Sire by sex and sire by management unit interactions in Simmental cross calves
by Robert Lars Friedrich

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Animal Science
Montana State University

Abstract:
Field records from the American Simmental Association representing creep fed (CF) and non-creep fed (NCF) progeny from approximately 100 different purebred sires were analyzed using least squares mixed model procedures. Non-creep fed and creep fed data sets were subdivided into 1/2 and 3/4 Simmental cross populations, (NCF 1/2, CF 1/2, NCF 3/4 and CF 3/4, respectively) with 1,185, 4,033, 4,106 and 8,612 progeny per population, respectively, and analyzed separately due to confounding with management unit. Dependent variables were birth weight, preweaning average daily gain (ADG) and weaning weight. Independent variables were management unit (weaning weigh date within breeder number), sire, sex (bull or heifer), age of dam (2 through 5 years or older), sex by age of dam and sire by sex in Model I and sire by management unit in Model II.

Under Model I, birth weight, ADG and weaning weight were significantly affected by management unit, sire, sex, age of dam and sire by sex in all populations. Estimates of the percent of the total variation for sire and sire by sex for birth weight were 5.7, 1.5; 7.2, 4.7; 2.8, .4 and 4.8, .5% for NCF 1/2, CF 1/2, NCF 3/4 and CF 3/4, respectively. The percent of the total variation for ADG and weaning weight were essentially identical for both sire and sire by sex and were 2.7, 1.8; 1.4, 1.7; 2.4, .3 and 2.5, .6% for the NCF 1/2, CF 1/2, NCF 3/4 and CF 3/4 populations, respectively.

The genetic correlations (rge) of the sires' progenys performance within the two sexes for NCF 1/2, CF 1/2, NCF 3/4 and CF 3/4 were .77, .51, .82 and .89 for birth weight; .41, .33, .82 and .67 for ADG and .49, 2.7, .88 and .77 for weaning weight, respectively.

Only NCF 1/2 and NC 3/4 data were analyzed under Model II. Birth weight, ADG and weaning weight were significantly affected by management unit, sire, sex and age of dam in both populations. Sire by management unit was significant for all traits in the NCF 3/4 data only. The percent of the total variation in the NCF 3/4 data for sire and sire by management unit were 3.9, 6.6; 3.7, 3.3 and 4.0, 3.6% for birth weight, ADG and weaning weight, respectively. The rge for the NCF 3/4 data were .37, .53 and .53 for birth weight, ADG and weaning weight, respectively. The significance of the sire by sex and sire by management unit interactions and the rge's suggest that in some cases sires may be changing rank in the different environments. The presence of these significant interactions would indicate that more work in the area of genotype by environment interaction may be necessary for the future improvement of the beef industry.

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by

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ABSTRACT

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Only NCF 1/2 and NC 3/4 data were analyzed under Model II. Birth weight, ADG and weaning weight were significantly affected by management unit, sire, sex and age of dam in both populations. Sire by management unit was significant for all traits in the NCF 3/4 data only. The percent of the total variation in the NCF 3/4 data for sire and sire by management unit were 3.9, 6.6; 3.7, 3.3 and 4.0, 3.6% for birth weight, ADG and weaning weight, respectively. The r_{ge} for the NCF 3/4 data were .37, .53 and .53 for birth weight, ADG and weaning weight, respectively. The significance of the sire by sex and sire by management unit interactions and the r_{ge}'s suggest that in some cases sires may be changing rank in the different environments. The presence of these significant interactions would indicate that more work in the area of genotype by environment interaction may be necessary for the future improvement of the beef industry.

INTRODUCTION

The objective of a sound animal breeding program would be to change the average genotype of a population as fast as feasible in a direction which would improve the performance of the population. Two elements of knowledge will be required: 1) the environmental influences and their effects on the population must be predicted and 2) selection must be based on the most accurate indicators of the performance of the population in the different environments.

Changes in phenotypic ranking of different genotypes under various environments could hinder the progress of animal breeding programs. Progress becomes increasingly more difficult depending upon the degree of genotypic and environmental interactions present in the various populations.

"The inability to appraise accurately the influences of general feeding and management conditions 'environments' on a sire's proof probably accounts for most of the mistakes in selecting proved sires" (Legates et al., 1956). It is with this thought in mind that the present study was undertaken. The objectives of the study were to examine the effects of several environmental and genotypic influences on the postnatal growth of Simmental cross progeny and to assess the importance of two specific genotype by environment interactions (sire by sex and sire by mangement unit interactions).

The sire by sex interaction may be important in terms of accurate sire evaluation. It is widely accepted that one of the best procedures for accurate evaluation of beef sires is through progeny testing. Presently, however, the majority of the progeny tests being conducted do not consider the presence of an important sire by sex interaction. Examination of the sire by sex interaction in these data will hopefully aid in answering some of the questions concerning this particular genotype by environment interaction.

The second interaction, sire by management unit, will also be examined to gain additional knowledge about whether or not it is one with which the industry must be aware of and use in the pursuit of the superior genotypes. If the sire by management unit interaction is found to be an important part of the variation associated with the performance traits, it may be necessary to more completely evaluate these interaction effects on the selection programs used in todays beef cattle industry.

LITERATURE REVIEW

General

Selection of individuals to be used in any breeding program is the framework for genetic improvement in any species. Certain genetic principles are present in all populations as outlined by Lush (1945). Some of these properties of Mendelian genetics include:

a) The genes of a specie are not adaptably modified by their environment.

b) Observed yields of gene combinations are affected by the environment.

c) The homozygosity of a population is changed only by selection, inbreeding or crossing of distinct lines. Mutation is rare and genetic drift is slow due to large populations.

d) Genes will interact with one another.

The above concepts express the basis of selection within a given population. Research has confirmed these principles but the application of them requires much more work in the area of identification of important alleles and the interpretation of the multitude of effects of each allele on the population. Important breakthroughs in chemistry and statistical theory are being made presently in this direction.

The ideas of envionmental influences upon population genetics alluded to above has led to some basic philosophies of genotype by environment interactions. Hammond (1947) believed that selection of individuals within a population would be most advantageous if carried

out in the environment which would best favor or enhance the particular trait in question. Upon fulfillment of the selection goals within this environment, the individuals could then be utilized in other less favorable environments for that particular trait. The new environments must, however, be satisfactory for other traits or criteria necessary for the maintenance of the population.

Other work in the area of genotype by environment interactions yielded varying philosophies. Lush (1945) and Falconer (1952) both expressed the view that selection of an individual trait or combination of traits would be best exemplified by selection within the environment the individual would be expected to perform. Dickerson (1962) theorized that in a broad sense there are no "independent" variations in the performances of animals due to their genotype and environment. The phenotypic expression of an individual's genotype requires a relatively fixed sequence of environments. Also, the influence of an environment occurs only as a change in the phenotypic expression of a well integrated genotype.

Dickerson (1962) hypothesized that differences in phenotypes between genotypes could remain constant under differing environments. This would indicate that there are average "genetic" and "environmental" effects contributing to the performance of an individual, as well as additional variation due to the combined effects of genotype and environment. This additional variation is not predictable from the

individuals average effects.

Hull and Gowe (1962), after reviewing the literature, deducted that if a stock of animals from previous generations had been selected for "high" performance in some trait, they could not be expected to do consistently well in all environments. They felt it was fair to assume that optimum performance could only be reached by selection under the conditions that would be prevelant during the future of that particular population.

Several important questions were asked by Robertson et al. (1960):

"Does the environmental level affect the ability to pick the animals of superior genetic merit in that environment?"

In other words "is the heritability different in the different environments?"

"Is the ranking of animals on the basis of genetic merit the same in all environments?"

Or "what is the correlation between 'breeding value' in the different environments?"

"Is there an interaction between genotype and environment?"

The concept of genotype by environment interaction may be expressed as a correlation if only two environments are considered (Falconer, 1952). The response of a measured trait in two different environments may be considered to be a single trait which has a defined genetic correlation. This concept would allow one to determine

whether or not a trait should be selected in the environment in which the animal will be utilized or in the environment which would more fully allow the expression of the trait in question.

An expansion on this theory was presented by Robertson (1959). He reported that the expression of a genetic correlation for a trait in multiple environments could be assessed through the use of mean squares from a factorial analysis of variance. The interaction of a genotype by environment may be assessed from the variance of the genotype between each environment from the variable ranking of genotypes within each environment. Thus a genetic correlation of 1.00 would indicate no interaction.

It was shown by Falconer and Latyszewski (1952) that if selection was more effective in a favorable environment, that environment must be able to reduce the random environmental variation which normally lowers the correlation between genotype and phenotype. This would mean that the heritability of the trait would be higher in a favorable environment as opposed to a less favorable environment.

Classification of Interactions. The classification of interactions was alluded to by Haldane (1946). He demonstrated that with two genotypes and two environments there would be six different combinations of responses to the two environments by the two genotypes. He further showed that with M genotypes and N environments there would be a possible $\frac{(M\ N)1}{M1\ N1}$ different types of interactions.

McBride (1958) pursued the question of genotype by environment interaction in a somewhat different manner. His classifications of genotypes and environments dealt with 'inter' and 'intra' populations or genotypes and 'micro' and 'macro' environments. McBride's theory would yield four classifications of interactions. These classification of interactions would be based upon differing responses of 'intra'-populations within 'micro' and/or 'macro'-environments and 'inter'-populations within 'micro' and/or 'macro'-environments.

McBride's classification of 'macro' environments would include climatic differences as well as major differences between management practices. 'Micro' environments would be a classification including minor environmental differences such as changes in a population's behavior or sub-clinical infections within the population for a particular macro-environment. Population differences would be those between (inter) or within (intra) breeds, lines or strains of individuals. These types of interactions could individually incorporate any or all of the classifications outlined by Haldane (1946).

Evidence has shown that such "intangibles" as social behavior ("peck order") in domestic fowl or certain behavioral patterns in swine can lead to interactions between micro-environments and intra-population genotypes without the presence of an interaction between macro-environments and the same intra-population genotypes.

Interactions have a definite relation to animal selection within breeds or lines of a specific specie. The existence of this interaction may necessitate the practice of selection within the environment for which the animal is to respond. Many workers have observed or studied this type of interaction and will be reviewed in following sections. The presence of this type of interaction was felt by McBride (1958) to be a very important source of variation in large animal selection.

An interaction involving inter-population genotypes and micro-environments is not generally thought to be important in the field of applied genetics. However, the ideas on heterosis suggest that heterozygous genotypes are capable of handling a wider range of micro-environments than homozygous genotypes. Micro-environmental fluctuations may cause some populations (purebred) to vary while there is no variation exhibited by other populations (hybrids). The contributions of a strain to the genotype environment interaction may be due to the differences in variation between the strains.

The interaction of inter-population genotypes with macro-environments will influence important decisions in animal breeding. Before an animal breeder can select the breed or strain for his environmental situation he must first test for the presence of this interaction. He must then determine whether or not the conditions under which he is to perform his selection are important, that is,

whether or not an intra-population by macro-environment interaction exists. "The existence of highly adapted local races of many organisms suggests that this interaction may be extremely prevalent". McBride (1946).

Dunlop (1962) classified genotype-environment interactions by categorizing the differences in genotype and environments as being "large" or "small". Large genetic differences would be those associated with between breed or strains and small differences as being within breed or strains. The environmental differences would include within region or management practices (small) or across regions or management practices (large). These classifications are essentially the same as those described by McBride (1958).

Dunlop (1962) maintained that the important genotype by environment interactions would be the ones involving a "large" genotype classification.

Pani and Lasley (1972) summarized many of the above principles into a classification system that most adequately exemplifies the genotype by environment interaction. Utilizing the statistical significance of differences in magnitude of change as well as ranking of genotypes within an environment they were able to more accurately determine the impact of a genotype-environment interaction. Figure 1 contains the four possible classifications of these interactions.

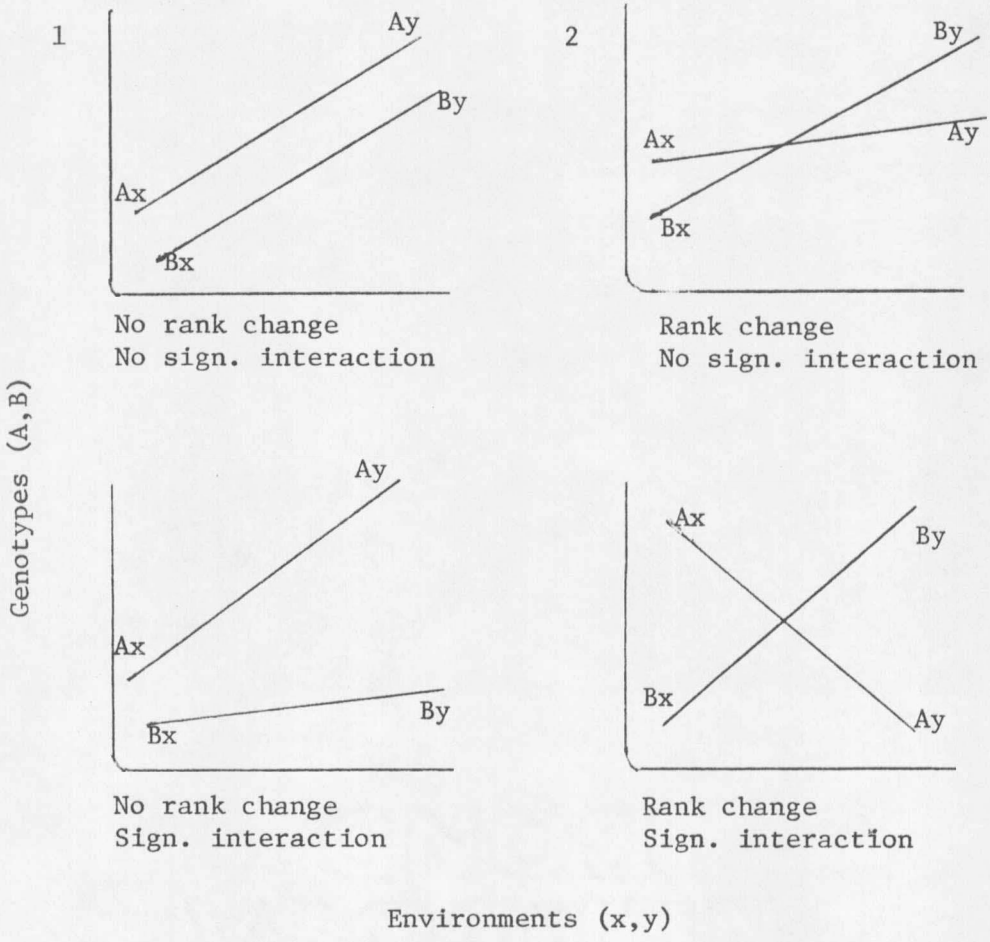

Figure 1. Four different types of genetic by environment interactions. (Pani and Lasley, 1972)

A significant interaction could result in either a change in ranking of genotype (Type 4) or a change in magnitude of genotype response (Type 3).

Sources of Environmental Variation (Beef Cattle)

Throughout the literature the primary sources of environmental variation which were examined were: sex of calf, age of dam and year of birth or season within year. Also examined were the effects of herd and nutrition. One other environmental sources is whether or not calves are creep fed during the preweaning period.

All of these sources as well as others have been found to have varied and/or predictable influences on the traits, birth weight, preweaning average daily gain (ADG) and weaning weight. In the following sections the effects of these sources of variation will be reviewed for an understanding of their importance and contribution to genotype by environment interactions.

Sex of Calf. Traditionally sex of the calf has been recognized as one of the prime sources of environmental variation in the birth weight, average daily gain and weaning weight of beef calves. It has been consistently reported throughout the literature that male calves were heavier than female calves at birth. This was found by Woodward and Clark (1950), Koch et al. (1959), Marlowe et al. (1965), Brinks et al. (1971), Kress and Webb (1972), Nelsen (1976) and many others within the Hereford and Angus breeds of cattle. The difference in birth weights generally falls within a range of 1.5 to 2.5 kg with

males being heavier. Taylor et al. (1960) reported a difference of 2.0 kg (29.1 vs. 27.1 kg, males vs. females, respectively) in Angus calves and a difference of 2.3 kg (31.8 vs. 29.5 kg, males vs. females, respectively) in Hereford calves. In a study involving 5,067 Angus birth weights and 4,778 Hereford birth weights, Marlowe (1962) found a difference of 2.0 kg and 1.8 kg within the two breeds, respectively, with male calves being heavier ($P<.01$) than female calves.

Laster et al. (1973) reported that male calves from Angus dams were 3.2 kg heavier than female calves and male calves from Hereford dams were 2.9 kg heavier than female calves. Smith et al. (1976) reported that males were 2.7 kg heavier at birth than females (36.3 vs. 33.6 kg, respectively) in a study involving 2,368 calves from Hereford and Angus dams sired by Hereford, Angus, Jersey, South Devon, Limousin, Charolais and Simmental bulls.

Anderson and O'Mary (1974) reported that Simmental sired bull calves from Angus dams were 5 kg ($P<.01$) heavier than contemporary heifer calves (42.8 vs. 37.8 kg, respectively). Simmental bull calves were found to be 3.6 kg heavier ($P<.01$) than heifer calves (42.2 vs. 38.6 kg, respectively) in a study of 20,949 calves conducted by Burfening et al. (1977). Laster et al. (1973) examined the differences between male and female birth weights of calves sired by Simmental bulls. The difference between birth weights of male and female calves from Angus dams and Simmental sires was 5.5 kg (37.8+.6 vs. 32.3+.6 kg,

respectively). This difference was the largest single difference within the seven breeds of sire analyzed. Calves from Hereford dams and Simmental sires followed this same trend with males being 3.2 kg heavier than females.

Much of the reported differences in birth weights between male and female calves is thought to be associated with the fact that gestation length is generally longer in males than in females. This difference does not always explain the variation sufficiently, however. Gestation length for males was found to be 1.7 days longer (285.7 vs. 284.0 days, respectively) as reported by Smith et al. (1976) and was similar to the 1.9 days reported by Bellows et al. (1971) and the 1.2 days reported by Cundiff et al. (1974). Even though gestation length was a significant source of variation for birth weight the differences in birth weights between males and females remained significant when this effect was statistically removed (Smith et al. 1976).

Sex of the calf is also a significant contributor to differences in preweaning average daily gain between male (bull and steer) and female calves. Marlowe et al. (1965), Kress and Webb (1972). Schaeffer and Wilton (1974a) and others have all reported significant effects of sex on ADG. Work with Hereford and Angus calves by Tanner et al. (1970), Brinks et al. (1972) and Brinks and Knapp (1975) revealed that bull calves gained between .04 and .06 kg per day more

than heifer calves. Nelms and Bogart (1956) reported that sex was not a significant source of variation on ADG in Angus male and female calves. Their findings indicated that the adjustment of sex for birth weight was enough to remove the effect of sex on ADG. Woodward and Clark (1950) also reported that sex of the calf was not a significant source of variation for ADG. Burfening et al. (1977) reported that sex was an important ($P<.01$) source of variation for ADG in Simmental sired calves. The bull calves gained .08 kg per day more than the heifer calves.

The effect of sex of the calf is generally significant for weaning weight, and in all cases the bull or steer calves are heavier than their heifer contemporaries. These differences as reported in the literature are usually within the range of 10 to 25 kg for bulls vs. heifers and 5 to 20 kg for steers vs. heifers. Brinks et al. (1961), Pahnish et al. (1961), Linton et al. (1968), Tanner et al. (1970), Kress and Webb (1972) and Nelson (1976) all reported these trends with Hereford and Angus calves. Cundiff et al. (1966) reported that steers were 5.1 kg ($P<.01$) heavier than heifers at weaning and that bulls were 25.3 kg ($P<.01$) heavier than heifers at weaning. Differences between bulls and steers may be in part due to the stresses of castration as well as confounding of selection pressures with superior males being retained as bulls with the remaining males being castrated.

Woodward and Clark (1950) reported that sex of the calf was not significant for weaning weight even though it was significant for birth weight of the same individuals. They did report that the calves with the larger birth weights were also larger at weaning.

A study conducted on 11,740 three-quarter Simmental cross calves found that bull calves were 19 kg ($P<.01$) (260 vs. 249 kg) heavier than heifer calves, (Friedrich et al. 1975). Burfening et al. (1977) studied 9,301 one-half and 11,648 three-quarter Simmental cross calves and found a difference of 19 kg ($P<.01$) (221 vs. 240 kg) in favor of the bull calves.

Age of Dam. The chronological age of a calf's dam is also considered to be one of the more important sources of environmental variation for birth weight, ADG and weaning weight of beef calves.

A dam's first calf is traditionally her smallest in terms of birth weight with subsequent calves being heavier until she reaches her mature size and age. As a dam nears the end of her productive lifetime, the birth weights of her calves may decrease slightly. This same trend generally applies to ADG and weaning weight of her calves.

Marlowe (1962) reported that birth weights of Hereford and Angus calves increase at a rate of .75 kg per year of age of the dam up to 6 or 7 years of age. At this time they start to decrease. Lasley et al. (1961), Koonce and Dillard (1967) and Kress and Burfening (1972)

reported that peak production in terms of birth weight was reached at 6, 8 to 11 and 5 years of age, respectively, in Hereford dams. Nelsen (1976) found that age of dam effects were maximized at 5 through 10 years of age in both Hereford and Angus dams. He reported that birth weights were 2.2, 1.0, 0.5 and 0.0 kg lighter in 2, 3, 4 and 11 year old dams of Angus breeding, respectively, when compared to 5 through 10 year old dam averages. In Herefords the differences were 3.2, 0.9, 0.0 and -.9 kg for the 2, 3, 4 and 11 year old dams, respectively.

Burfening et al. (1977) reported differences of 6.9, 5.3, 4.2 and 1.4 kg ($P<.01$) in birth weights of Simmental cross calves from 2, 3, 4 and 5 year old dams when compared to 6 through 8 year old dams, respectively. The mean birth weights were 35.9, 37.5, 38.6, 41.4 and 42.8 kg for the 2, 3, 4, 5 and 6 through 8 year old dams, respectively.

Laster et al. (1973) reported that age of dam had a significant effect on birth weights of calves born from Hereford and Angus dams. Birth weights of calves from 2 year old dams were 2.7 kg lighter than calves from 3 year old dams and 3.6 kg lighter than calves from 4 and 5 year old dams. The difference between birth weights of calves from Simmental sires were 3.1 kg for calves from 2 and 3 year old dams and 2.7 kg for calves from 2 and 4 or 5 year old dams.

The influence of the dam's age on birth weight as reported by Smith et al. (1976) was not consistent among breed crosses. The Simmental, Limousin and Charolais cross calves tended to have birth

weights which increased at a slower rate as the cows neared maturity than did the calves from Hereford, Angus, Jersey and South Devon crosses. The increase in birth weights of the calves from 2 to 3, 3 to 4 and 4 to 5 and older ages of dam averaged .4, 1.1 and 1.6 kg, respectively, for the Hereford, Angus, Jersey and South Devon dams and 2.0, 1.9 and .8 kg, respectively, for the Limousin, Simmental and Charolais dams.

The effect of age of dam was called "the most important source of variation" for the ADG of Angus and Hereford calves by Marlowe and Gaines (1958). Cunningham and Henderson (1965), Marlowe et al. (1965) and Kress and Webb (1972) all reported that age of dam was a significant source of variation on ADG in Hereford and Angus calves. Schaeffer and Wilton (1974a) examined records of 25,571 Angus and 68,053 Hereford calves and found highly significant age of dam effects on ADG. Nelms and Bogart (1956) and Tanner et al. (1970) both determined that the effect of age of dam on ADG only approached significance. Smith et al. (1976) reported that ADG was significantly affected by age of dam. The respective values for ADG of calves from 2, 3, 4 and 5 year or older dams were .69, .78, .85 and .87 kg per day, respectively. Also examined was the relative preweaning growth rate expressed as the percentage change in body weight per day of age. Age of dam also significantly affected this trait with mean values of .82, .86, .88 and .88 for 2, 3, 4 and 5 year old or older dams, respectively.

The age of dam effect on ADG in Simmental calves was found by Burfening et al. (1977) to be highly significant. The largest ADG was within the 4 year old dams with the "mature" cows being slightly lower, (.96 vs. .93 kg per day, respectively) probably due to some confounding of age of dam and percentage of Simmental breeding in the different age groups. The ADG of the calves from the 2 and 3 year old dams were .87 and .92 kg per day, respectively.

Studies involving Hereford and/or Angus calves by Kress and Webb (1972) and Kress and Burfening (1972) showed that age of dam was a significant source of variation for weaning weights. These researchers reported that peak production for this trait was reached at 5 to 10 years of age. A study involving 19,907 Hereford and Angus records conducted by Sellers et al. (1970) also revealed that the age of dam affected ($P<.01$) weaning weights of the progeny. The maximum production in the study was between 6 through 12 years of age with a decrease in the weaning weights of calves whose dams were over 12 years of age.

Progeny from 2 and 3 year old one-half Simmental dams were used in a study by Friedrich et al. (1975). Calves from 2 year old dams were 9 kg lighter than calves from 3 year old dams (254 vs. 263 kg, respectively). Burfening et al. (1977) also examined records of Simmental sired calves. Their study also reported peak weaning weights of calves from dams 5 through 8 years of age. The study did not contain any dams older than 8 years however. The differences

between the 2, 3 and 4 year old dams with the 5 through 8 year old dams were -21, -8 and 0 kg, respectively ($P<.01$).

Year Effects. The effects of year and/or month or season of birth on birth weight, ADG and weaning weight have been reported in the literature as being varied and to a certain degree controversial. It is generally thought that such traits as ADG and weaning weight would increase over years due to selection for these traits. Not all researchers are able to show this trend, however. Primarily the time effects fluxuate from time period to time period with only limited predictability.

Season and month of birth were reported to have a significant effect on birth weight by Lasley et al. (1961) and Wilson et al. (1972). Koonce and Dillard (1967), Kress and Webb (1972) and Burfening and Kress (1973) all reported that year of birth was a significant source of variation for birth weight in Hereford calves. Sagebiel et al. (1973) reported that there were differences in birth weights from year to year but there was no indication of any trend for increased weights over the years involved. Conversely, Burris and Blunn (1952) reported that year was not a major source of variation for birth weight on a within sex and breed basis. Their feelings were that management practices from year to year were able to effectively removed the variation of yearly environmental fluxuations. The study conducted by Nelsen (1976) on field records involving Angus and Hereford cattle

revealed that year did in fact significantly affect birth weight and that a linear relationship did exist. He reported that from 1958 to 1971 there was an average increase in birth weight of -29 kg per year over all herds in the study.

Preweaning average daily gains are also affected by year (Cunningham and Henderson, 1965; Kress and Webb, 1972 and Nelsen, 1976). Studies by Marlowe et al. (1965) on 17,294 Angus and 11,663 Hereford calves over 6 years and by Schaeffer and Wilton (1974b) on 16,524 Angus and 47,293 Hereford calves over 2 years both showed significant year effects on ADG. The study of Marlowe and coworkers did not indicate that there was a trend for increased ADG over years. The variation was one of fluxuation rather than uniformity.

Cundiff et al. (1966), Linton et al. (1968), Sellers et al. (1970) and others have reported that season of birth or month of birth has a significant effect on weaning weights of beef calves. Sellers et al. (1970) reported that weaning weights of calves born during December through May were over 7 kg heavier than calves born from June through August and 5 kg heavier than those born from September through November. Cundiff (1966) also reported increased weaning weights of calves born during the winter and early spring months as opposed to those born during the summer and fall. The study conduced by Friedrich et al. (1975) on Simmental calves followed the afore mentioned trends. Calves

weaned in January through March were 27 kg lighter than calves weaned in July through September (243 vs. 270 kg, respectively).

Year effects on weaning weights have also been widely reported to be significant throughout the literature. Cundiff et al. (1966), Busch and Dinkel (1967), Linton et al. (1968), Tanner et al. (1970) Kress and Webb (1972) and Burfening and Kress (1973) all reported that year was a significant source of variation on weaning weight in Hereford and Angus calves. Bailey et al. (1977) reported that year was a significant but variable source of variation for weaning weight in Hereford cattle. The difference between maximum and minimum annual weaning weights were 22.4 kg for the unadjusted weaning weight and 15.2 kg for the weaning weights adjusted for age of calf and metabolic size of the dam. The majority of the reported studies do not reveal any general trends toward increased weaning weight over years. Nelsen (1976), however reported that weaning weight increased significantly during the time span of this study (1.62 and 2.29 kg per year ($P<.01$) for Hereford and Angus calves, respectively).

Management Practices (Creep feeding vs. no creep feeding). One source of environmental variation which may be directly associated with management practices is creep feeding of calves (supplying additional nutrition to preweaning calves above that supplied by the dam).

Several studies have been conducted by Nelson (1952, 1954, 1955)

at Oklahoma State University involving creep feeding. The effects of creep feeding on average daily gain indicated that increases of as much as .11 kg per day could be achieved. Kennedy and Henderson (1975b) studied 61,680 Hereford and 27,333 Angus calves that were either creep fed or not creep fed in Canada. On a within creep or no creep and breed basis, they found that calves which had been creep fed gained .06 and .01 kg per day more than those which had not been creep fed in the Hereford and Angus breeds, respectively. Schaeffer and Wilton (1974a) reported significant increases in ADG of creep fed calves over non-creep fed calves. Both Angus and Hereford creep fed calves gained .05 kg per day more than non-creep fed contemporaries.

The effect of creep feeding on weaning weights of beef calves was generally reported as a significant effect. Weaning weights of creep fed calves were consistently heavier than those of non-creep fed calves. Nelson et al. (1952, 1954), Cundiff et al. (1966) and others have all reported significant increases in weaning weights of calves which had been creep fed during the preweaning period. Sellers et al. (1970) found that creep feeding Hereford and Angus calves significantly increased weaning weights 19.1, 10.2 and 13.0 kg over the non-creep fed contemporaries in bulls, steers and heifers, respectively. Kennedy and Henderson (1975b) examined approximately 83,000 records of creep fed and non-creep fed Hereford and Angus calves. On a within creep or no creep feeding and breed basis, the creep fed Angus calves were 3 kg

heavier and the Hereford calves were 13 kg heavier than the corresponding non-creep fed calves.

The effect of creep feeding in the "exotic" beef breeds is paralled to that of the British breeds. Friedrich et al. (1975) reported that creep fed Simmental calves were 11 kg ($P<.05$) (264 vs. 253 kg) heavier at weaning than non-creep fed calves. Anderson and O'Mary (1974) also reported significant differences in creep fed and non-creep fed Simmental and Chianina cross calves.

Other Environmental Sources of Variation. Several other environmental sources of variation are also reported in the literature. These include herd or ranch effects as well as regional or location effects.

Several studies have examined the environmental effects of herd or ranch on birth weight, ADG and weaning weight. Barlow et al. (1974) and Koonce and Dillard (1967) both reported that herd was a significant source of variation for birth weights of Hereford and Angus calves. Nelsen (1976) also found significant differences between herds of purebred Angus and Hereford cattle.

Average daily gain and weaning weight were also affected by herd or ranch. Mahmud and Cobb (1963) and Barlow et al. (1974) reported significant herd effects on ADG as did Pahnish et al. (1961), Cundiff Cundiff et al. (1966) and Nelsen (1976) for weaning weight. Rankin and Holland (1974) studied the effects of breed of sire, breed of dam and ranch on the weaning weights of Hereford and Brangus calves. Adjusted

205-day weights were 206.1 kg. Calves on the foothills ranch were 26.7 kg heavier than the calves at the desert ranch. The interaction between ranch and breed of dam was highly significant for weaning weight. Brangus cows produced calves which were 24.1% (41.4 kg) heavier than Hereford cows at the desert ranch but only 9% (18.9 kg) heavier at the foothills ranch. The effect of herd or ranch will be reviewed in more detail later under the section dealing with variance components of random effects with respect to birth weight, ADG and weaning weight.

The importance of region of the country was examined by Nunn (1974). He reported that region of the country was not a significant source of variation on birth weight or weaning weight of Simmental cross calves. This was expected due to the nature of the data analyzed (ratios were used instead of actual values). He did state that region may still be important enough to consider during evaluation of sires for use in artificial insemination programs. Cundiff (1966) reported that area of the state (Oklahoma) was a significant source of variation for weaning weights of Angus and Hereford cattle.

Interactions Between Environmental Sources of Variation. The importance of interactions between environmental sources of variation with wide ranges of phenotypic expressions need to be examined in full detail. These interactions may be of practical importance in the selection of the animals for use in the beef industry. The important

interactions to be reviewed were those involving sex of the calf, age of dam, preweaning management practices such as creep feeding and no creep feeding as well as the interactions involving time trends.

Sex of Calf by Age of Dam Interaction. Nelsen (1976) reported that within Hereford and Angus calves the sex by age of dam interaction was significant in the Angus calves ($P<.01$) but was not as important for the Hereford calves ($P>.10$). The average differences between Angus bull and heifer calves from 2, 3 and 4 year old dams was 1.8 kg. This difference for mature Angus dams (5 years old or older) was 2.2 kg. This trend suggested that the uterine environment may have been a limiting factor for male birth weights in younger cows due partially to the size of the cow as compared to the mature dam. The bull calves were reaching the limits of their prenatal growth due to the reduced space limitations while the heifers being naturally smaller were able to grow to a larger relative size, especially in younger dams.

Burfening et al. (1977) reported a significant sex by age of dam interaction for birth weight of Simmental cross calves. He reported differences of 2.8, 3.2, 3.4 and 3.7 kg in birth weights for bull and heifer calves from 2, 3, 4 and 5 through 8 year old dams, respectively.

Average daily gains have also been shown to be significantly affected by the sex of the calf by age of dam interaction. Schaeffer and Wilton (1974a) and Burfening et al. (1977) reported that the sex by age of dam interaction was a significant source of variation for ADG.

The latter reported that in Simmental cross calves, the difference between bull and heifer ADG from 2 and 3 year old through 8 year old dams was .06 kg per day and .08 kg per day, respectively. Cunningham and Henderson (1965) and Kress and Webb (1972) both reported that the sex by age of dam interaction did not significantly affect the ADG in Hereford and Angus calves. Nelsen (1976) found this interaction to be important ($P<.05$) in only the ADG of the Angus calves in his study involving Angus and Hereford calves.

Friedrich et al. (1975) found that this interaction was not important in Simmental cross calves from only 2 and 3 year old dams. Conversely, Burfening et al. (1977) reported singificant ($P<.01$) differences between bull and heifer weaning weights from 2 and 3 through 8 year old dams. This difference was 15 kg in the calves from 2 year old dams and 21.8 kg in the calves from the 3 through 8 year old dams.

Sex of Calf by Year, Month and/or Season of Birth. The effect of sex by year and/or other time trends has been examined on a limited basis. Tanner et al. (1970) and Barlow et al. (1974) both reported that sex of calf by year was a significant source of variation on ADG. Schaeffer and Wilton (1974a) reported that the sex by year interaction was only significant for ADG in the Hereford calves of their study involving Hereford and Angus calves. In all cases the variation seems to be a random one without any significant time trends involved.

Cunningham and Henderson (1965) found that sex by year only approached significance for ADG.

Sex of calf by year was shown to be a significant source of variation in weaning weights of Hereford and Angus calves by Pahnish et al. (1961), Cooper et al. (1965) and Linton et al. (1968). Pahnish did note that this interaction was only evident in one of the two ranches used in the study with no evidence of any specific time trends.

Sex by season of birth was found to be significant for weaning weights by Cooper et al. (1965) In Simmental cross calves, Friedrich et al. (1975) reported that sex by season of weaning was a significant source of variation on weaning weights. No specific information was presented concerning time trends or conclusions at that time.

Sex by Herd, Ranch or Region. A significant sex of calf by herd interaction was reported by Nelsen (1976) for birth weight and ADG of Angus and Hereford calves in his study. His data indicated that herds with higher mean birth weights exhibited greater sex differences than herds with lower mean birth weights. Pahnish et al. (1961) reported that sex by ranch was a significant interaction for weaning weight as did Nelsen (1976). In both cases the studies were performed with Hereford and Angus data. The significant variation of sex by herd in the latter study was attributed to random fluxuations only. Mainly, the effect of sex by herd, ranch or region has been found to be of no consequence on the weaning weights of the calves studied.

Sex by Preweaning Management (creep or no creep feed). Marlowe et al. (1965) and Scarth et al. (1968) reported that creep feeding of steers resulted in faster growth rates than the creep feeding of heifer contemporaries. This study was done on a within creep feeding or non-creep feeding basis. Marlowe and coworkers reported that steer calves grew 6% faster than heifer calves regardless of whether they were creep fed or not. Non-creep fed bull calves grew 6.6% faster than non-creep fed steers and creep fed bull calves grew 9.7% faster than creep fed steer calves. They suggested that possibly different adjustments are needed for sex when calves are managed under a creep feeding system. Schaeffer and Wilton (1974a) also reported that sex by creep feeding was a significant interaction for ADG in beef cattle. Cundiff et al. (1966) did find a significant interaction of sex by creep feeding system for weaning weights but later concluded that on a practical basis the interaction was not important. The interaction of sex by creep feeding on weaning weights of Simmental cross calves was not significant as reported by Friedrich et al. (1975).

Age of Dam by Year, Month or Season of Birth. The interactions between age of dam and the time effects (year, month or season of birth) have been studied by various researchers with varying results. Schaeffer and Wilton (1974) studied the effects of age of dam by year interactions on ADG. They reported that this interaction was important in only the Angus progeny in their study involving both Angus and

Hereford cattle.

Weaning weight has also been reported to be significantly affected by the age of dam by year interaction. Harwin et al. (1966), Sellers et al. (1970) and Cooper et al. (1965) all reported significant age of dam by year interactions for weaning weights. Cooper et al. (1975) reported that the age of dam effects were more consistent over years than they were over seasons. The variation attributed to the interaction was not uniform in nature but more random across time. Weaning weights of Simmental cross calves did not reflect any major age of dam by season of weaning influences as reported by Friedrich et al. (1975).

Age of Dam by Preweaning Management (creep or no creep) The interaction of age of dam by preweaning management (creep feeding or no creep feeding) may be of importance in the beef industry. It is possible to speculate that younger cows which produce smaller calves as reported earlier may be able to increase their production through creep feeding practices. The effect of age of dam by creep feeding was examined by Schaeffer and Wilton (1974a) for ADG. They reported that the interaction did not have an important affect on ADG. They did however, report that a significant age of dam by creep feeding by sex interaction did exist.

Cundiff et al. (1966) examined the effect of age of dam by creep feeding interactions on weaning weights in Hereford and Angus calves. They reported that there was no significant differences between

weaning weights of creep feed and non-creep fed calves from younger or older dams. They did indicate that utilization of creep feeding by calves from 2 year old dams and very old dams (15 years old or older) may compensate slightly for the lower milk production of these dams. Also, calves out of 2 year old dams which were creep fed deviated significantly less from the mean than did calves which were not creep fed. These trends were also reported by Marlowe and Gaines (1958) and Marlowe (1962). Weaning weights of Simmental calves from 2 and 3 year old dams that were creep fed or not creep fed were found to be significantly ($P<.10$) affected by the interaction of age of dam by creep feeding as reported by Friedrich et al. (1975). Creep fed calves whose dams were 2 years of age were 14 kg heavier at weaning than the non-creep fed calves from 2 year old dams while creep fed calves from 3 year old dams were only 8 kg heavier than the non-creep fed contemporaries. This would indicate that the calves from the 2 year old dams may be utilizing the creep feeding to a better advantage than the calves from the 3 year old dams.

Genetic Sources of Variation (Beef Cattle)

The primary sources of variation associated with genetic influences involve breed, breed cross, line or to a degree inbreeding as well as the effect of individual sires. These sources of variation have been examined by numerous researchers for birth weight, preweaning average daily gain and weaning weight in beef cattle. Emphasis on breed

sources will be within the British breeds as well as the several "exotic" breeds previously mentioned.

Breed and Breed Cross Variation. It has been widely accepted that differences do exist between breeds for birth weight, ADG and weaning weight. Burris and Blunn (1952) reported that birth weights of Angus and Hereford calves were significantly different. Their study revealed that Angus calves were 1.5 kg lighter than Hereford calves at birth (29.2 vs. 30.7 kg, respectively). In 1960, Taylor et al. (1960) reported that Hereford calves were 5.7 kg heavier than Angus calves at birth. Most studies revealed that the differences fell within a 3 to 5 kg range with Herefords being larger at birth. Foote et al. (1960) reported that Shorthorn calves were on the average 2 kg lighter than Angus calves at birth.

Sagebiel et al. (1973) reported that there were differences in birth weights between Angus, Charolais and Hereford cattle. Charolais calves were significantly heavier than Hereford and Angus calves and Hereford calves were significantly heavier than Angus calves. These weights were 43.6, 33.4 and 26.3 kg for the Charolais, Hereford and Angus calves, respectively.

Long and Gregory (1974) studied the effect of breed of sire on birth weight using Angus and Hereford sires mated to Angus and Hereford dams. Calves by Hereford sires were 1.4 kg heavier than calves from Angus sires. Gregory et al. (1965) also observed a similar but

larger difference (3.8 kg) between birth weights of Hereford and Angus sired calves from Hereford, Angus and Shorthorn dams. Observations of larger birth weights of calves sired by Hereford bulls have been reported by Pahnish et al. (1969) and Turner and McDonald (1969).

Angus dams gave birth to significantly smaller calves than did Hereford dams as reported by Long and Gregory (1974), 28.9 vs. 30.6 kg for Angus and Hereford dams, respectively). Results reported by Long and Gregory (1974) were consistent with those reported by Gregory et al. (1965), Wiltbank et al. (1967), Pahnish et al. (1964), Laster et al. (1973) and Laster and Gregory (1973).

Stanforth and Frahm (1974) reported that Simmental sired calves from Angus dams were heavier ($P<.05$) at birth than any other breed group studied other than the Brown Swiss sired calves from Hereford dams. The mean birth weight of the Simmental by Angus calves was 36.1 kg and Brown Swiss by Hereford, Brown Swiss by Angus, Hereford by Angus and Simmental by Hereford calves had similar birth weights ranging from 34 to 35 kg. Jersey by Hereford, Angus by Hereford and Jersey by Angus calves weighed 29.4, 29.3 and 28.2 kg, respectively, at birth, and were lighter ($P<.05$) than the other breed cross calves.

Meiske and Goodrich (1975) examined the differences in birth weights of Hereford, Chianina and Marchigiana sired calves

from mature Angus dams. They reported that Marchigiana and Chianina sired calves were heavier ($P<.05$) than Hereford sired calves at birth (36.0, 34.2 and 31.5 kg, respectively). They also reported evidence of greater sexual dimorphism in birth weights of the Chianina sired calves over the Marchigiana and Hereford sired calves.

Crocket and Koger (1975) examined birth and weaning data from calf crops over a 3 year period to compare 5 breeds of sires - Brahman, Brangus, Limousin, Maine-Anjou and Simmental - bred to Angus, Brangus and Hereford dams. Average birth weights were 34.0, 33.1, 32.2, 32.2 and 29.0 kg for the Brahman, Maine-Anjou, Limousin, Simmental and Brangus sired calves, respectively.

In studies involving breed crosses it is not uncommon to find larger birth weights in the crossbred calves than either of the parental breeds. Bradley et al. (1966) reported that the birth weights of Hereford by Red Poll calves were larger than the straight-bred Hereford calves. Angus, Brahman, Brangus and Hereford cattle were used in a study by Turner et al. (1969) to evaluate the effects of straight breeding, cross breeding, back crossing and three way crossing on birth weights and several other traits. They reported that mating types were all significant for birth weight of the calves involved and that breed of sire was also a significant source of variation for birth weight.

Breed of calf has been shown to have an effect on ADG of beef calves. Turner and MacDonald (1969), Sellers et al. (1970) and Bradley et al. (1966) all reported significant breed differences for ADG of the different breeds of calves studied. Anderson and O'Mary (1974) reported that Simmental cross and Chianina cross calves grew at a significantly faster rate than Angus calves. This difference was .12 kg per day in favor of the "exotic" breeds of crosses over the Angus calves. Long and Gregory (1974) reported that preweaning average daily gains were greater ($P<.01$) in Angus sired calves than in Hereford sired calves, (.64 vs. .62 kg per day for Angus and Hereford calves, respectively). These values are in contrast to those reported by Gregory et al. (1965), Turner and MacDonald (1969) and Cundiff et al. (1970) who reported no differences in the ADG between Angus and Hereford calves. Melton et al. (1967) felt that Angus dams provided a maternal environment more conducive to preweaning growth than did Hereford or Charolais dams. He indicated that this was due to higher milk production and occurred even in the presence of creep feeding. Gregory et al. (1965), Gaines et al. (1966), Pahnish et al. (1969) and Cundiff et al. (1970) all reported similar results when comparing ADG of calves from Angus and Hereford dams. Sagebil et al. (1974) examined the ADG of progeny from Angus, Hereford and Charolais dams and sires. The ADG of the prgoeny was not significantly affected by the breed of sire but was significantly affected by breed

of dam. Charolais dams produced calves which gained significantly faster than Angus or Hereford dams and Angus dams likewise produced calves which gained faster than Hereford dams.

Many of the previous studies involving ADG also reported that weaning weight is also significantly affected by breed of calf. Long and Gregory (1974) reported that 200-day adjusted weaning weights of Angus sired calves were 4.1 kg ($P<.01$) heavier than those sired by Hereford bulls, (158.2 vs. 154.1 kg, respectively). Sagebiel et al. (1974) reported that breed of sire had a significant effect on 205-day weights of Angus, Hereford and Charolais calves. Charolais sired calves were heavier ($P<.05$) than Angus and Hereford sired calves. Cundiff et al. (1966) found that Angus calves were 2.2 kg heavier at weaning than the Hereford calves used in their study. They did indicate that even though the Hereford calves were smaller and difference was not considered to be of major importance.

Weaning weights of Simmental sired calves from Angus dams were significantly heavier than calves from the other breeds studied by Stanforth and Frahm (1974). Jersey sired calves and Angus by Hereford calves were lightest at 205 and 210 kg, respectively. Brown Swiss by Angus and Simmental by Hereford calves weighed 226 and 224 kg, respectively, and were 8 kg heavier than the Hereford by Angus and Brown Swiss by Hereford calves. In the study by Crocket and Koger (1975), it was reported that the 3 year average 205-day weights were

213, 212, 208, 198 and 197 kg for the Maine-Anjou, Simmental, Brahman, Brangus and Limousin sired calves, respectively.

Line, Crossline or Inbreeding Sources of Variation. The effect of specific line within a breed has been examined as a contributing source of genetic variation in beef cattle. The emphasis on line breeding and to a certain degree inbreeding, is important to more fully evaluate the traits of birth weight, ADG and weaning weight.

Harwin et al. (1966) reported that linecrossing and inbreeding of the calf both are significant sources of variation on weaning weight. Weaning weight was also significantly affected by line of dam in Hereford calves studied by Kress et al. (1973). These differences ranged from -13.7 to 5.1 kg about a mean of 185 kilograms. Inbreeding of the calf was found to be a signficant source of variation on weaning weights by Brinks and Knapp (1975). For each percent increase in inbreeding of the calf, the weaning weights were -.29 and -.30 kg less in male and female calves, respectively. Inbreeding of the dam also was reported to be a significant sources of variation for weaning weights.

Bailey et al. (1977) reported that neither line of sire nor line of dam were a significant source of variation for weaning weight in Hereford calves.

Sire Sources of Variation. The sire effect on the various traits of economic importance in todays beef industry is unquestionably

important. The advent of artificial insemination in the beef industry will necessitate that proper sire selection be practiced. Sire evaluation within the dairy industry has made great strides in the improvement of dairy animals and can be of equal value in the beef industry. Therefore, the knowledge and understanding of sire variation is a useful tool in the selection of sires.

Birth weights were found to be significantly affected by sire of the calf in Hereford and Hereford/Angus studies conducted by Gregory et al. (1950) and Kress and Webb (1972). Woodward and Clark (1950) reported significant sire effects for birth weights. Wilson et al. (1969, 1972) reported that sire was not a significant source of variation for birth weight.

Nunn (1974) examined 6,222 birth weights from Simmental sires used in artificial insemination progarams from throughout the United States. He reported that sire was a significant source of variation for birth weights. He also reported that individual sires differed by 3.2% below the average to 1.4% above the average of all sires in the study.

Sire effects have been shown to be of importance in ADG of beef cattle, Cunningham and Henderson (1965), Tanner et al. (1970), Thrift et al. (1970) and Kress and Webb (1972) all reported significant sire effects on ADG. On the other hand, Gregory et al. (1950) and Wilson et al. (1969) reported that sire did not affect ADG.

Weaning weights of calves are affected by sire as well. Knapp and Phillips (1942), Pahnish et al. (1961), Wilson et al. (1969), Kress and Webb (1972) and others have shown this to be true. Kress and Webb (1972) reported that means of individual sires within years indicated differences in progeny groups from 1 to 33 kg in Angus and 3 to 35 kg in Hereford calves. Woodward and Clark (1950) and Wilson et al. (1972) could not find a significant sire effect for weaning weight. Simmental sires reported on by Nunn (1974) were found to be a significant sources of variation for weaning weight. The various sires examined differed as much as 3.8% to -1.2% based on the overall means for the weaning weight trait ratios in his study.

Interactions Between Genotypic Sources of Variation. Turner and MacDonald (1969) examined the effects of breed of sire by mating systems; straightbred, single cross, backcross and three way cross in Angus, Brahman, Brangus and Hereford calves. They reported that the interaction of breed of sire by mating system was significant for birth weight, ADG and weaning weight. In a study involving five inbred lines of Hereford cattle, Brinks et al. (1962) found that line of sire by line of dam interaction was not a significant source of variation for birth weight. In a later study by Brinks et al. (1972) they found a nonsignificant line of sire by line of dam effect on the same preweaning traits.

In Hereford cattle, Kress et al. (1973) found that ADG was significantly affected by the line of sire by line of dam interaction. Humes et al. (1973) could not find this trend in either birth weight or weaning weight.

Sagebiel et al. (1973) reported that there was no significant interaction between breed of sire and breed of dam when comparing Charolais, Angus and Hereford breeds and their two way crosses for birth weight. They did note that Charolais cows had significantly heavier crossbred calves at birth than Angus cows and significantly heavier crossbred male calves than female calves when compared to the Angus dams. Angus and Hereford bulls did not significantly increase the birth weights of the crossbred calves but the Charolais bulls did. Humes et al. (1974) examined the data from 243 calves from Angus and Hereford dams sired by Brahman, Chianina, Maine-Anjou and Simmental bulls. There were no differences in the birth weights of the different breeds of sire in the study. The sires within breed were a significant source of variation on birth weight, however. There was also no significant breed of sire by breed of dam interaction. They suggested that in the Gulf Coast region, calves sired by Brahman, Chianina, Maine-Anjou and Simmental bulls out of Angus and Hereford dams, show no real differences in the birth and early growth traits.

Preweaning average daily gain of Angus, Charolais and Hereford progeny were examined by Sagebiel et al. (1974). A significant breed

of sire by year and breed of dam by year interaction within the heifer progeny was found. It was felt that both interactions may have been due to confounding of years and age of dam and therefore an indication of a genotype by age of dam interaction. A second order interaction of breed of sire by breed of dam by year also was noted in the study. They felt that it indicated that the bull breed by cow breed combination may respond differently in different years.

The line of dam by line of sire interaction was not significant for weaning weight as reported for Hereford cattle by Bailey et al. (1977). Sagebiel et al. (1974) reported that the breed of sire by breed of dam interaction was significant for weaning weights of the various crosses involved in their study.

Genotype by Environment Interactions (non-bovine)

Falconer and Latyszewski (1952) selected two strains of mice for six-week body weight. One strain was selected under a restricted diet and one strain was selected under a full diet. The environments were exchanged for the two strains after several generations of selection had been performed. The strain selected under the restricted diet performed better than the full diet strain under a restricted diet with the opposite relationship being the case in the unrestricted diet. In a similar study, Falconer (1960) concluded that selection should be performed in the environment in which the animal is expected to respond.

Fowler and Ensminger (1960) used data from 1,705 swine in nine generations of selection. Two lines (HH-High and LL-Low) were maintained for the first six generations of selection for average daily gain. After the sixth generation each line was divided into HH, HL, LH and LL lines. The four subsets were then selected through three more generations. Through the first six generations the HH line gained .043 lb/generation and the LL line .034 lb/generation. The next three generations resulted in the average daily gain from the LH pigs being the highest at 1.41 lb/day and the HL pigs the lowest at .94 lb/day. They concluded that breeding stock should be selected in the environment in which the progeny are expected to perform.

Lowry et al. (1956) were unable to demonstrate any significant shifts in progeny performance from varied strains of poultry between floor and cage housing systems. Gowe (1956) found highly significant interactions between seven leghorn strains with floor and cage housing systems on body weight but no indications of interactions for sexual maturity or egg weight. Gowe and Wakely (1954) found no real changes in the ranking of four strains between five geographical locations for number of hens at the onset or the survivors' egg production. Hill and Nordskog (1956) analyzed 14,000 pullets of 13 strains on 11 farms and reported important and highly significant stock by farm interactions for adult mortality, egg production, sexual maturity and egg size, but not for body weights. They also reported significant strain

by year interactions for egg production and adult mortality.

Dickerson (1962) examined poultry data from approximately 30,000 pullets over two years from a variety of strains and farms attempting to interpret evidence concerning genetic-environment interaction as it is related to effectiveness of selection. His results indicated that variations among poultry-farm invironments in California caused important but unpredictable shifts in the ranking of genotypes for egg production. Also reported was the fact that improvement in accuracy in measuring genetic differences in the indiviudals performance across environments justifies the utilization of at least five to 10 farms representing the range of environments for which the stock is bred.

Hull and Gowe (1962) studied the magnitude of genotype by environment interaction involving two strains of poultry, three widespread locations with two types of rearing per location over three years. Rearing treatments, year and farm effects were large but for the most part quite variable from year to year. Large interactions were found only when the environmental effects were large and the genetic differences wide.

King and Young (1955) studied the effects of genotype-environment interaction in sheep. Three breeds of sheep (Cheviot, Blackface and Wiltshire) were wintered in four different environments. The environments consisted of warm and cold climates with high and low nutritional

levels in each climate. There was a significant breed difference for growth traits with the blackfaced sheep growing faster in the high nutritional levels of each environment but there was no change in rank between breeds for any of the interactions in the study.

Morely (1956) divided groups of half-sib wethers into high and low planes of nutrition to be fed from three to 17 months of age. The findings involving the genotype-environment interactions indicated no significant interactions for any of the fleece traits or body weights up to six months of age. The interaction was significant for body weight at 12 and 17 months of age however. The findings indicated that genotype-environment interactions exist and are important considerations for selection. When two groups of crossbred twin lambs were used to study high and low planes of nutrition (King et al., 1959), no significant cross by plane of nutrition interactions were found.

Brown et al. (1961) examined the effects of sex by line of sire interactions on birth weight, 30-day weight, 120-day weight and number of days to reach 27 kg in body weight. Two inbred lines of Hampshire and Hampsire cross lambs were used in the study. The interaction between sex and line of sire was significant for only the trait of number of days to reach 27 kilograms.

Dunlop (1962), using five strains of Merino sheep run at three locations examined the strain by location interactions on wool traits.

The interactions of strain by location were real but small in magnitude and accounted for only a minor fraction of the total variation. The inconsistency of the interactions was reported to be due to climatic variation. He hypothesized that specific adaptation in these traits should not be considered for the choice of a strain for a particular location.

Dhaliwal et al. (1963) reported that an interaction between ewe and level of nutrition during late pregnancy did not affect the number of lambs born per ewe.

The effects of environment on phenotype and genotype variation in sheep was examined by Osman and Bradford (1965). Five years of data from two locations (high and low environmental classifications) were used to study genotype by environment interactions. Traits studied included body weights, gains and fleece traits through 450 days of age. Selection was based on 120 day weight. The trait variances were higher in the better environment resulting in a larger selection differential. The average paternal half-sib heritability was higher in the good environment but the realized heritabilities after three years of selection were not different. There was no evidence of large genotype by environment interaction. They also found increased reproductive performance in the good environments resulting in increased selection intensity.

The importance of genotype by environment (plane of nutrition)

interaction was studied by Osman and Bradford (1967). Forty ram lambs and 78 wether lambs from Targhee, Corriedale and Targhee by Corriedale crosses were used to evaluate body weight, gain, fleece and carcass traits. Sire by plane of nutrition interaction was significant but of no major importance in only five of the 38 traits studied.

Carter et al. (1971a) examined the effects of genotype by environment interactions on ewe productivity. Two distinct breed crosses, one from Ottawa, Canada, and one from Virginia, were used in the study. The two crosses of ewes were divided equally and removed to the opposite location. Location by breed cross interactions were significant for percent ewes lambing, weight of lamb weaned and average lambing date. The ewes from Virginia had an 11% better lambing rate in Virginia than the Ottawa ewes which were moved to Virginia. There was no difference in the lambing rates between the two crosses at Ottawa. The Ottawa ewes lambed 18 days earlier in Virginia but only one day earlier in Ottawa. There was a strong suggestion of location by breed cross interaction in body weight of the ewes and fleece weights of the ewes. They concluded that there was important breed cross by location interaction on ewe productivity probably due to climatic differences.

Carter et al. (1971b) followed up the above report on ewe productivity with an examination of the genotype by environment interaction on lamb performance. Significant breed cross by location

interactions were found for birth weight and adjusted 120-day weight but not for average daily gain. The differences were small in magnitude however. In conclusion, they reported that the effects observed in ewe productivity as well as lamb performance emphasized that local adaptation of breeds or breed crosses is of considerable importance with respect to the total production of the breed in a particular environment.

Genotype by Environment Interactions (dairy cattle)

Breed, Line or Strain by Environment Interactions. Foote et al. (1959) studied some of the effects of genetic and maternal environmental variations on birth weights and gestation length in Holstein cattle. They reported that line of sire was a significant source of variation for both birth weight and gestation length but that the line of sire by sex interaction was not significant for either trait.

In a study conducted by Brumby (1961), 240 calves from 20 high and 20 low producing herds were raised and milked in a single herd with production midway between the high and low producing herds. Also, 120 sets of identical twins were split between the 20 high and 20 low herds to be reared and milked. There was no general genetic differences between the cows from the high and low herds for body size, fertility and milk production, but there was some genetic differences in milk composition. Genetic differences for milk yield were found between the high herds but not the low herds. The interaction between

herd environment and genotype provided an appreciable source of variation. The production level of a herd in which an individual was reared was without effect upon subsequent production potential.

Thirty-seven identical Holstein twin heifer pairs were studied by Ramsay and Freeman (1965). The pairs were separated and assigned to a high or low level of nutrition or both placed on the high or low level. The variance within pairs was homogeneous across age for wither height but increased with age for body weight. The interaction component of variance was zero at younger ages but increased with time. At older ages, the interaction of pairs by rations was significant for wither height but not for body weight and accounted for 10% of the total variance in both traits. In a similar study by Burnside et al. (1969), 48 pair of fraternal male Holstein twins were reared on two rations. No significant pair by ration interaction was found for body weight or gain but calves on the high plane gained faster and grew to a larger size. These results have been substantiated by Freeman (1969), Burnside et al. (1972) and others. In all cases, ration by pair interactions were not significant for growth traits, live measurements or carcass traits.

Sire by Environment Interactions. Legates et al. (1956) examined records from 24,754 daughters of Guernsey, Holstein and Jersey sires to evaluate sire by herd interactions on production traits. Results of the study showed that the importance of the sire by herd interaction

was very small. The interaction component of variance within breed was never significant although the interaction component for the Jersey breed was almost as large as the sire component of variance. Wadell and McGilliard (1959) and McDaniel and Corley (1967) also determined that the sire by herd interaction component was a very small portion of the total variance.

Van Vleck et al. (1961) studied 40,000 records from Holstein sires in New York state. They found that 50% of the total variation in production was due to sire, herd and year plus the two-way interactions. Herd effects accounted for 30% of the total with sire and year accounting for 6 and 2%, respectively. Sire by herd and sire by year were very small but herd by year was approximately 5% of the total variation.

Lactations from Holstein cows from different herds were examined by Van Vleck (1963). The herds were divided into four classifications (High to Low) based on production. The results indicated that there was no sire by herd level of production interaction. The genetic variance was greater in the high production herds than in the low production herds. Mason and Robertson (1956) reported similar results along with increased heritabilities in the high producing herds. Robertson et al. (1960), Legates (1962) and McDaniel and Corley (1967) substantiated these results, that variation between progeny groups was greater at higher levels of production. Not all researchers

found that heritability increases as the level of production increases. Robertson et al. (1960) and Legates (1962) found no difference in heritabilites at different herd levels of production. They felt this was due to the increased within sire variance at the higher levels of production.

Van Vleck (1963) calculated genetic correlations between progeny groups in the four production levels to be from .93 to 1.00. Others have also reported similar correlations of near unity for sire evaluations at different herd levels of production. This would indicate that the ranking of sires from one level of herd production to another would be approximately the same.

Burdick and McGilliard (1963) studied 10,000 artificial inseminated daughters from Holstein and Gurnsey sires to evaluate sire by environment interactions. Interactions involving sire by level of production, location, days dry, calving interval or type of housing were examined. Small differential responses of daughters within classifications were found but all appeared to be unimportant. The ranking of sires was determined to be the same in any of the environments examined.

Artificial insemination sires were evaluated by Mao and Burnside (1969) on a within season and environment category. Each environment was evaluated independently as fixed effects. The different environments consisted of types of housing, breeding programs used, herd sizes and other management practices. No sire by environment interaction

was found except for sire by grain-feeding level in summer. This particular interaction component of variance accounted for 17% of the total variation. Wiggans and Van Vleck (1970) also found no significant sire by housing system (free vs. station) interaction. Using 1,000 herds and approximately 20,000 lactations, the genetic correlation was equal to 1.00 indicating no change in rank for sires under either system.

Lytton and Legates (1966) studied the sire by region interaction on milk production traits in Holstein sired cows. The correlation between breeding values of the sires in the northern vs. southern regions of the United States approached 1.00 indicating no change in the ranking of the sires. The sire by region interaction component of variance was essentially zero.

Genotype by Environment Interactions (beef cattle)

The effects of interactions involving various genotypes and environments have received attention in the past. The general approach to evaluate the different interactions is to evaluate the genotype within the particular environments involved. It is therefore evident that proper evaluation of genotype by environment interactions should be conducted in the area of beef cattle production.

The particular breed one will use within a beef production program is based upon many different criteria. The personal preference of the producer, availability of breeding stock as well as the size of

the operation, the types of climate involved, the market for calves in his area and many more variables are involved in the choice of the particular breed to be used by the producer. Several researchers have examined some of the breed by environment interactions which may have significant impact on birth weight, ADG and weaning weight of the beef cattle to be used by the producers.

A study involving Hereford and Red Poll calves was conducted by Bradley et al. (1966) to examine the effect of breed of dam by sex of calf interaction. They found that breed by sex interaction was not a significant factor in assessing birth weight variation in beef cattle. Ellis et al. (1965) and Laster et al. (1973) both reporting on Hereford and Angus breeds of cattle found that sex of calf by breed of sire interaction was a significant source of variation on birth weight. In both cases the difference was one of magnitude as opposed to changes in the ranking of the sexes by breed for birth weight. Breed of calf by sex of calf interaction was examined by Cardellino and Frahm (1971) using Hereford and Angus cattle and the interaction was not found to be significant. Analysis of breed differences by Gregory et al. (1966a,b) showed that Angus bull calves were heavier at weaning than Hereford bull calves but that there was no difference between the Angus and Hereford heifer calves.

A breed by age of dam interaction was examined by Sellers et al. (1970) with approximately 20,000 Hereford and Angus calves. The

analysis was conducted on a within sex basis. Breed by age of dam was a significant source of variation for weaning weights of bull calves only. This interaction was also found to be significant by Cardinello and Frahm (1971) in Hereford and Angus calves. In both cases the younger Angus dams reared larger calves than the younger Hereford dams. The difference was less for the older and more mature dams.

Long and Gregory (1974) found that the interactions of breed of sire and breed of dam with year ($P<.05$) for preweaning growth were due to differences in magnitude rather than rank of the breed of sire or breed of dam subclasses from year to year. They were therefore not considered to be of any major importance. Icaza et al. (1974) examined the differences between breed of dam and age of dam and found a significant ($P<.05$) interaction for weaning weight. The differences between the weaning weights of the male progeny from Brahman and Brangus dams compared to those from Angus and Hereford dams of 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12+ year old dams was 10.7, 44.7, 21.0, 29.4, 22.7, 8.5, -3.9, -.3, 26.2 and 11.5 kg, respectively. They felt that these results indicate that cattle with Brahman breeding lactate more heavily at earlier ages and maintain their productivity longer in the Gulf Coast region than Angus and Hereford dams.

Cardellino and Frahm (1971) found breed by year to be a significant source of variation but there was no trends other than in certain years the difference was greater than in other years. Turner and

MacDonald (1969) also found significant breed by year effects using several different beef breeds in their study.

Breed by season of birth when analyzed on a within sex basis was highly significant for the bull, steer and heifer weaning weights of calves examined by Sellers et al. (1970). In all cases the constant estimates of the interaction cells of the model changed significantly for each breed by season subcell. These changes were both in sign and magnitude. Cundiff et al. (1966) also reported a significant month of birth by breed interaction for Hereford and Angus calves but indicated that the interaction was of small importance in the overall analysis.

Birth weight was significantly affected by the breed of sire by year interaction in the study by Sagebiel et al. (1973). Three years and three breeds of sire (Angus, Charolais and Hereford) were examined. They felt that the significant breed of sire by year interaction was possibly due to a sire effect as different groups of three sires within each breed were used each year. They did indicate that a genotype by environment interaction may have been present.

Line of dam and line of sire by year interactions were examined by Brinks et al. (1967), using five Hereford lines of cattle. Neither interaction was significant for birth weight or weaning weight. Urick et al. (1968) noted significant line of sire by year interaction on weaning weights of female calves in the study but not male calves. Line of dam by year was not significant for either sex.

A line of sire by age of dam interaction was found to be a significant source of variation for weaning age and subsequent unadjusted weaning weights of Hereford calves as reported by Bailey et al. (1977). The line of dam by sex interaction was found by Bailey et al. (1977) to be a significant source of variation on weaning weights of Hereford calves. Inspection of the subclass means revealed that the "line 2" dams raised larger bull calves than did the "line 1" dams but heifer progeny from "line 1" dams were larger at weaning than contemporaries produced by "line 2" dams.

The interaction of sire by sex of calf for birth weight, ADG and weaning weight have been examined by various researchers with beef cattle. Calves of Hereford and Hereford by Red Poll crosses and Hereford and Angus crosses were studied by Bradley et al. (1966) and Kress and Webb (1972). In both cases the sire by sex interaction was reported to be not important for birth weight. Others have also shown that sire by sex interaction was not a significant source of variation on birth weight, Tanner et al. (1960), Wilson et al. (1969) and Thrift et al. (1970).

The effect of sire by sex interaction was shown by Kress and Webb (1972) to be a significant source of variation on ADG in Hereford and Angus calves. Tanner et al. (1969), Tanner et al. (1970) and Thrift et al. (1970) did not find this interaction to be significant on ADG or weaning weight.

Wilson et al. (1969) found that sire by sex was significant for weaning weight as did Kress and Webb (1972) in the Hereford calves used in their respective studies. Pahnish et al. (1961) and others were unable to establish significant sire by sex interactions for weaning weights. Kress and Webb (1972) determined that the significant sire by sex interaction was due to changes in rankings of the sires and would therefore be an important source of variation for weaning weight.

An analysis of 5,000 beef and dairy cross calves was conducted by Edwards et al. (1966) with sire by year being a significant source of variation for weaning weight. Brinks et al. (1967) also reported a significant sire by year effect on weaning weight in female Hereford calves.

Sire by location was found to be significant in a study by Edwards et al. (1966) for birth weight but not significant in a study by Woodward and Clark (1950) for ADG. Ninn (1974) reported that with Simmental sires there was a significant sire by region of the country interaction for weaning weight. He pointed out that within region sire evaluations should be carried out.

Phenotypic and Genetic Correlation Between Birth Weight, Preweaning Average Daily Gain and Weaning Weight

The phenotypic correlations between birth weight and preweaning average daily gain were generally reported as being between .10 and .40. Brinks et al. (1961) reported a phenotypic correlation of .12 and Koch et al. (1973) reported a phenotypic correlation of .18.

Other studies have reported this correlation to be higher, (Petty and Cartwright, 1966, .23; Brinks et al., 1964, .26; and Koch et al., 1973, .27). Nelsen (1976) reported that the phenotypic correlation between birth weight and ADG in Angus calves was .26 and in Hereford calves it was .19. Residual correlations between birth weight and preweaning average daily gain in Simmental calves was reported by Burfening et al. (1977) to be .29.

Genetic correlations between birth weight and average daily gain were generally similar to the phenotypic correlations. Koch et al. (1973) reported a genetic correlation of .10 between birth weight and ADG. Genetic correlations of .11, .38 and .46 have been reported by Brinks et al. (1962), Petty and Cartwright (1966) and Brinks et al. (1964), respectively, for birth weight and preweaning average daily gain. Nelsen (1976) reported genetic correlations between birth weight and ADG of .38 and .17 in Angus and Hereford bull calves, respectively. In Simmental cross calves, Burfening et al. (1977) reported a pooled genetic correlation of .17 for the two traits.

Phenotypic correlation between birth weight and weaning weight were generally larger than those for birth weight and ADG. Thre also appeared to be less variation among the reported estimates for the phenotypic correlations: Brinks et al. (1962) .30; Koch et al. (1973), .35; Petty and Cartwright (1966), .39 and Brinks et al. (1964), .41. The genetic correlations between birth weight and weaning weight were

also larger than those reported for birth weight and ADG. These correlations range from a .41 reported by Koch et al. (1973) to a .68 reported by Shelby et al. (1964). The average genetic correlation reported by Petty and Cartwright (1966) was .58. Burfening et al. (1977) reported a genetic correlation of .33 for these two traits.

As expected, due to the nature of the growth of young beef calves, the phenotypic and genetic correlations between preweaning average daily gain and weaning weight were almost unity. The reported correlations between these two traits were generally greater than .95 (Petty and Cartwright, 1966, .97 and .09; Koch et al., 1973, .09 and .95; Nelsen, 1976, .98 and .96 for Angus and .98 and .97 for Herefords and Burfening et al., 1977, .98 and .99 for the phenotypic and genetic correlations, respectively).

Variance Components for Several Random Effects Associated with Beef Cattle Production

Cundiff et al. (1975) examined the genetic variance associated with data from sires selected from herds of Angus and Hereford cattle. A model containing the random effects of year, herd within year and sire within herd within year plus the fixed effects of sex and breed of the dam was used to evaluate the genetic variation among and within different herds of beef cattle for the production traits from birth through slaughter and several carcass traits. The percentage of genetic variation associated with the herd effect for birth weight was 3.9±2.2. The corresponding variation for the sire within herd

effect was 2.4±2.3% of the total variation for birth weight.

Burfening et al. (1977) examined the variance components of management unit (herd weaning weigh date) and sire for birth weight, preweaning average daily gain and weaning weight. The variance components for management unit for the birth weights of the male progeny were 19.8% of the total variation associated with the model and the sire variance was 10.4% of the total variances in the model. These percentages were 26.7 and 7.5% for management unit and sire, respectively, in the female data. The pooled estimates of the variances associated with management unit and sire in their study were 23.8 and 7.8%, respectively.

The estimates of the variance components for herd and sire within herd for average daily gain were examined by Cunningham and Henderson (1965) using Hendersons Method II (1953) in Angus and Hereford data. Herds accounted fo 18% of the total variation in ADG in the Angus data and 15% in the Hereford data. The sire within herd variance component accounted for 11% of the variation in ADG in the Angus data and 10% in the Hereford data. The interaction between herds and years was more important in the Angus data at 9% of the total variation for ADG compared to the 3% variation in the Hereford data.

Kennedy and Henderson (1975) examined the variances associated with average daily gain as affected by year, herd, sire within herd, year by herd and sire within herd by year. Field data from creep and

non-creep fed Angus and Hereford progeny were used in the study. The variation associated with the year effect was small (<2%) and considered unimportant in the study. This was true in all but the creep fed Angus data where this effect accounted for approximately 4% of the total variation in ADG. All four data sets (non-creep and creep fed Hereford and Angus) contained substantial variation associated with the different herds in the study. This effect explained 25 to 27% of the variation in average daily gain of all data sets except in the creep fed Angus data where this effect explained 40% of the total variation. There was no apparent difference between the variation for herd in the Angus or Hereford data or between creep or non-creep fed progeny other than in the creep fed Angus calves. The sire within herd variation was found to be somewhat important in the explanation of the total variation and explained(5 and 7%) in the non-creep fed data and (3 and 4%) in the creep fed data. There was no difference between the Hereford and Angus data sets within the creep and no creep fed data.

Kennedy and Henderson (1975) also reported that herd by year was more important than the effects of year and sire within herd. This variance was 7, 9, 10 and 2% for the non-creep fed Hereford and Angus and creep fed Hereford and Angus data sets, respectively. The smaller year by herd interaction variance in the creep fed Angus data (2%) may be due to the larger year effect in this data set. Year by sire within herd was also considered to be of some importance. This effect

explained 4% of the variation in each of the non-creep fed data sets and 1 and 3% in the Hereford and Angus creep fed data sets, respectively. The error variance for the four data sets ranged from 47 to 56% of the total variation.

The above variance reported for ADG by Kenedy and Henderson (1975a) for the various sources of variation are exactly the same for weaning weight in their study. The year effect was small with the herd effect explaining between 25 and 41% of the total variation in weaning weight. Sire within herd was small but may be important at between 3 and 7% of the total variance. Any trends exhibited in the preweaning average daily gains were also found to hold true for weaning weight in their study.

Schaeffer and Wilton (1975) examined the weaning weight components of variance for sire and error in data from Charolais, Simmental and Limousin sired progeny. They reported that the sire variances were substantially larger for the Charolais progeny than for the Simmental and Limousin data. The error variances were vary similar. The resulting sire to error variance ratios were 7, 32 and 22 for Charolais, Simmental and Limousin data, respectively. The small sire variances in the data would necessitate large numbers of progeny per sire in order to properly evaluate the differences between sires.

Burfening et al. (1977) found that the management unit source of variation explained 44% of the variation in weaning weights of Simmental sired calves. The sire component of variance only accounted for 6% of the total variation but was considered to be of some biological value.

Heritability Estimates for Birth Weight, Preweaning Average, Daily Gain and Weaning Weight

The heritability studies for birth weight most often deal with the estimates derived from the paternal half-sib correlations. These results as published in summaries by Preston and Willis (1974) have an average value of .38 using all breeds of cattle and a value of .44 as reported by Petty and Cartwright (1966) in only beef cattle. The heritability estimates for birth weight of calves sired by Simmental bulls was .42 in the case of male data only and.30 for female data with combined estimate of .31 as reported by Burfening et al. (1977).

The heritability estimates for preweaning average daily gain are generally about .30. Petty and Cartwright (1966) reported a summarized weighted average of .31 when the overall average of .26 was adjusted for the numbers of progeny per estimate. Cunningham and Henderson (1965) estimated the heritability of average daily gain from the variance component analyses on an intra- and inter- herd basis by the use of the following formula:

intra-

$$h^2 = \frac{4\sigma^2_{s/h}}{\sigma^2_{s/h} + \sigma^2_e}$$

inter-

$$h^2 = \frac{4\sigma^2_{s/h}}{\sigma^2_h + \sigma^2_{s/h} + \sigma^2_e}$$

where the $\sigma^2_{s/h}$ term is the sire within herd variance, σ^2_h is the herd variance and σ^2_e is the residual variance from a mixed model situation using Hendersons Method II (1953). They had assumed that the identifiable environmental variation was corrected for and that there was stable gene frequencies, no epistatic gene action and random mating within the population was present. They reported heritability estimates of .59 and .47 for the Angus data for the intra- and inter- herd basis, respectively and .50 and .42 for the Hereford data for the intra- and inter- herd basis, respectively. They felt that these estimates were large due to biases in the variance components with regard to maternal and other sources of genetic influences not being accounted for by the model.

Kennedy and Henderson (1975a) reported heritability estimates for ADG to be between .20 and .42. Their study involved Hereford and Angus data from creep and non-creep fed progeny in herds throughout Canada. These estimates were not unlike those reported in previous studies. There were two trends indicated in the estimates however, 1) the heritability estimates for ADG were larger in the Angus data than the

Hereford data .42 vs. .32 in the non-creep fed populations, respectively, and .28 vs. .20 in the creep fed population, respectively, and 2) the heritability estimates for ADG were larger in the non-creep fed populations than in the corresponding creep fed populations (see above values).

Cundiff et al. (1975) reported that on a within herd basis the heritability of preweaning average daily gain for a combined Angus and Hereford study was .10±.10.

The heritability estimates for weaning weight as summarized by Nelsen (1976) within the beef breeds was about .31. If this estimate was weighted by the number of sires in the different studies, this value was .41. Weighting by the number of progeny per study resulted in a hertibaility estimate of .39 for weaning weight. A weighted mean of .28 was reported by Petty and Cartwright (1966). Preston and Willis reported an average value of .30 for the heritability of weaning weight. Nelsen (1976) reported a heritability estimate of .15 for weaning weight of the Angus bull calves which was lower than the estimate obtained from the Angus heifer data (.28) and the Hereford bull data (.33).

The heritability estimates for weaning weight reported by Kennedy and Henderson (1975a) were similar to those reported for preweaning average daily gain in their study. The non-creep fed progeny had larger estimates (.33 and .44, Hereford and Angus, respecively)

than the estimates from the creep fed data (.19 and .20, Hereford and Angus data, respectively) and were larger in the Angus data than in the Hereford data.

Burfening et al. (1977) reported that the heritability estimates for weaning weight for Simmental sired calves was .22 when pooled over the two sexes.

MATERIALS AND METHODS

Field records supplied by the American Simmental Association from their 1976 sire evaluation program were used in the study. The records represented approximately 350,000 progeny from more than 700 purebred Simmental sires. The sires were used in artificial insemination breeding programs in herds located throughout the United States.

The use of field records inherently contain some disadvantages. The records were collected without direct supervision and may have been subject to greater errors than records collected under controlled situations. Indentification of individuals, accuracy of measuremnts and completeness of the individuals records are additional problems associated with the use of field records. Attempts to remove some of these errors in the data were done through several edits which were performed on the data prior to analysis.

The data were edited with records excluded from the study according to the criteria shown in table 1. Records without an actual birth weight, weaning weight, birth date for the dam or a weaning age of less than 160 days or greater than 250 days were deleted. Experimental evidence has indicated that calf growth is linear within the 160 to 250 day age range, but that linear growth is not maintained within substantially wider age ranges (Cunningham and Henderson, 1975).

TABLE 1. EDITS FOR THE VARIOUS TRAITS

Trait	Edit criteria
All traits	Any percentage of Simmental breeding other than 1/2 or 3/4 was deleted
	All steer data was deleted
	Any progeny record with an age of dam less than one year nine months was deleted
Birth weight	Only actual birth weights were retained
	Birth weights less than 18.2 and greater than 77.2 kg were deleted
Weaning weight	Weaning weights less than 90.9 and greater than 453.6 kg were deleted
	Weaning ages less than 160 and greater than 250 days were deleted

Only progeny records from one-half and three-quarter Simmental calves were retained. Preliminary subcell counts indicated that there would be insufficient steer data and therefore all steer data was excluded from the data base. Ages of the dams were calculated according to the current B.I.F. (1976) recommendations and records from dams less than one year nine months of age were deleted. All dams whose age was greater than five years were reclassifed as being five years of age (mature). These dams ranged from 5 to 11 years of age. Management units were designated as individual weaning weigh dates within breeder number. Management unit therefore accounts for herd, year and season of birth in the analyses.

Due to confounding of preweaning management (creep feedings vs. no creep feeding) within management unit, the data base was further edited to remove any management units which were cross classified for creep and non-creep fed progeny.

The use of management units with both creep fed and non-creep fed progeny would have resulted in the use of only a limited amount of the data available. The lack of cross classified management units is understandable in this instance where field records are being utilized. The use of creep or no creep would obviously be used across an entire mangement unit, and only in limited cases would it be possible for the manager of the ranch to use both creep and no creep feeding within the individual management unit.

The nature of the data being from the relatively recently introduced Simmental breed to the United States also meant that the amount of Simmental breeding in the progeny would be less than 100%. In the data available, the predominate breeding of the progeny was either 1/2 or 3/4 Simmental. As with the practice of creep and no creep feeding within management unit the data was also confounded for the amount of Simmental breeding in the individual management units.

The data base was therefore subdivided into four subfiles according to preweaning management (creep or no creep feeding) and the amount of Simmental breeding in the calves (1/2 or 3/4), (CF 1/2, CF 3/4 and NCF 1/2, NCF 3/4, respectively). These data files were then edited to inusre that there were two sires per management unit with one or more of the sires being a designated reference sire. A reference sire is one which had 300 or more progeny from 25 or more management units for weaning weight in the 1976 sire summary for the American Simmental Association (sire summary reference).

The requirement for two sires per management unit and one reference sire was made in an effort to decrease the amount of disconnectedness between management units. The estimation of the management unit variances requires at least some form of ties between the different management units. The requirement of two sires and the use of the designated reference sires would fulfill this requirement.

The statistical methods employed (Mixed Model Least Squares, Harvey, 1973) necessitated that for the particular models utilized in the analyses of the data there be an upper limit on the number of sires that could be present in the individual data sets. This limitation resulted in a simplified process of iterative edits where by any sire with fewer than a predetermined number of progeny were deleted until only the proper number of sires remained in the data sets. All sires were given a coded identification number for use in the analyses. The sire list with the number of progeny per sire and the number of management units in which the sire was used is given in appendix table 1 for each subfile.

The number of progeny and other descriptions of the final data sets are presented in table 2.

The four data sets were each used to study the effects of environmental and genetic sources of variation and interactions associated with the dependent variables of birth weight, preweaning average daily gain (ADG) and weaning weight.

TABLE 2. NUMBER OF OBSERVATIONS PER DATA SET AND OTHER DESCRIPTIONS OF THE DATA SETS FOR MODEL I

Item	Data set			
	NCF 1/2	CF 1/2	NCF 3/4	CF 3/4
No. observations	4106	1885	8612	4033
No. sires	45	44	45	46
No. males	867	280	2541	1359
No. females	3239	1605	6071	2674
Age of dam				
2 yr	300	83	4671	2124
3 yr	686	402	2449	1288
4 hr	716	289	1202	495
5 or older	2404	1111	290	126
No. management units	224	83	563	196

Two models were used to analyze the effects of environmental and genetic sources of variation and interactions on the dependent variables. Model I was used to evaluate the effect of the sire by sex interaction within the four data sets. Model I was $Y_{ijkl} = u + H_i + S_j + X_k + A_l + (SX)_{jk} + (XA)_{kl} + e_{ijklm}$ here Y_{ijkl} = the observed individual's response with u = the population mean, H_i = a random variable associated with calves of the j^{th} sire, X_k = a fixed effect common to the calves of the k^{th} sex, A_l = a fixed effect common to the calves from the 1^{th} age of dam, $(SX)_{jk}$ = a fixed effect common to the calves of the i^{th} sire and the k^{th} sex, $(XA)_{kl}$ = a fixed effect cmmon to the calves of the k^{th} sex and the 1^{th} age of dam, e_{ijklm} = the random error associated with the record of the m calf distributed with the mean zero and variance σ_e^2. Interactions between management unit and the fixed effects and the sire by age of dam interaction were assumed to be negligible at this time.

The following assumptions with regard to the distributions of the random effects were made: $H_i = N(\mu, \sigma_H^2)$, $e_{ijklm} = N(\mu, \sigma_e^2)$; S_j, X_k, A_l, $(SX)_{jk}$ and $(XA)_{kl}$ were considered to be independent and uncorrelated.

The expectations of the mean squares were presented in table 3 for Model I. The variances for the model were calculated as described by Harvey (1972) from the various inverse elements and coefficients equated during the analytical procedures employed by the program.

Due to limited confounding of sex within sire within management unit, the data were reedited with the restriction that at least one sire of the two or more sires required within each management unit be cross classified with sex. The resulting low numbers of progeny in the creep fed data sets necessitated their removal from the study. The resulting data sets were described in table 4. The remaining two data sets were analyzed according to Model II to evaluate the sire by management unit interaction effect on birth weight, preweaning average daily gain and weaning weight. Model II was $Y_{ijkl} = u + H_i + S_j + (HS)_{ij} + Y_k + A_l + (XA)_{kl} + e_{ijkl}$ = the observed individuals response with u = the population mean, H_i = a random variable associated with calves born in the 1^{th} management unit, S_j = a fixed effect common to the calves of the j^{th} sire, $(HS)_{ij}$ = the effect common to the calves born in the 1^{th} management unit and from the j^{th} sire, X_k = a fixed effect common to the calves of the k^{th} sex, A_l = a fixed effect common to the calves of the 1^{th} age of dam, $(XA)_{kl}$ = a fixed effect common to the calves of the k^{th} sex from the 1^{th} age of dam, e_{ijklm} = the random error associated with the record of the m^{th} calf distributed with mean zero and variance σ_e^2. Interactions of management unit with the remaining fixed effects were assumed to be non-existant.

TABLE 3. EXPECTATIONS OF THE MEAN SQUARES FOR MODEL I.

Sources	E.M.S.
Management unit	$\sigma_e^2 + k_h\sigma_H^2$
Sire	$\sigma_e^2 + k_s\sigma_S^2$
Sex	$\sigma_e^2 + k_k\sigma_K^2$
Age of dam	$\sigma_e^2 + k_a\sigma_A^2$
Sire by sex	$\sigma_e^2 + k_{sx}\sigma_{SX}^2$
Sex by age of dam	$\sigma_e^2 + k_{xa}\sigma_{XA}^2$
Residual	σ_e^2

TABLE 4. NUMBER OF OBSERVATIONS PER DATA SET AND OTHER DESCRIPTIONS OF THE DATA SETS FOR MODEL II

	Data set	
	NCF 1/2	NCF 3/4
No. observations	1068	3378
No. sires	45	44
No. males	513	1592
No. feamles	555	1786
Age of dam		
2 yr	159	1722
3 yr	173	1038
4 yr	213	522
5 or older	523	96
No. management units	24	85

The following assumptions concerning the various effects were made: $H_i = N(0,\sigma^2_H)$; $S_j\ (HS)_{ij} = N(0,\sigma^2_{HS})$; $X_k = 0$; $A_l = 0$; $(XA)_{kl} = 0$; $e_{ijklm} = N(0,\sigma^2_e)$; S_j, X_k, A_l and $(XA)_{kl}$ were considered independent and noncorrelated.

The expectations of the mean squares for Model II are presented in table 5. The variance components and their coefficients of variation were computed as described by Harvey (1972) form and various inverse segments of the data matrix during the computational procedures involved in the solution of the model.

Variance components were obtained for the random managment unit effect (σ^2_H) and the sire (σ^2_S) and the sire by sex interaction (σ^2_{SX}) for Model I. The total variance associated with Model I was calculated as being $\sigma^2_T = \sigma^2_H + \sigma^2_S + \sigma^2_{SX} + \sigma^2_e$. The total variance associated with Model II was calculated as being $\sigma^2_T = \sigma^2_H + \sigma^2_S + \sigma^2_{HS} + \sigma^2_e$, where σ^2_{HS} = the sire by management unit interaction variance component.

Genetic correlations of the sires' progeny performance within the two sexes (Model I) or within the management units (Model II) were calculated to estimate the importance of the sire by sex and sire by management unit interactions for birth weight, preweaning average daily gain and weaning weight. No interaction would be indicated by a genetic correlation of unity. It has been suggested by Robertson (1959) that a figure of less than .80 may denote a biologically important interaction.

TABLE 5. EXPECTATIONS OF THE MEAN SQUARES FOR MODEL II

Source	
Management unit	$\sigma_e^2 + K_4\sigma_{HS}^2 + K_5\sigma_H^2$
Sire	$\sigma_e^2 + K_2\sigma_{HS}^2 + K_3\sigma_S^2$
Sire by management unit	$\sigma_e^2 + K_1\sigma_{HS}^2$
Sex	$\sigma^2 + K_x\sigma_X^2$
Age of dam	$\sigma_e^2 + K_a\sigma_A^2$
Sex by age of dam	$\sigma_e^2 + K_{xa}\sigma_{XA}^2$
Residual	σ_e^2

The genetic correlations of the sires' progeny performance within each sex was approximated according to: $$r_{ge} = \frac{\sigma_S^2 - \frac{1}{k}\sigma_{SX}^2}{\sigma_S^2 + \frac{k-1}{k}\sigma_{SX}^2} \quad (1)$$ as presented by Yamada (1962), where k = the number of sexes involved. The genetic correlation of the sires' progeny performance within each management unit was also calculated by the above method. The k in this instance was equal to the number of management units in the study within each data set and σ_{HS}^2 was substituted for σ_{SX}^2 in formula 1.

The sampling variance of the genetic correlation coefficient $V(r_{ge})$ for only two environments, as in Model I, was approximated according to:

$$V(r_{ge}) = \frac{\{nt(1-r_g^2) + (1-t)\}^2 + r_g^2(1-t)^2}{(N-1)n^2t^2} + \frac{r_g^2(1-t)^2}{N(n-1)n^2t^2}$$

as presented by Robertson (1959), where $t = \frac{\sigma_S^2}{\sigma_T^2}$, n = the average number of progeny for the sire by sex interaction subclasses, N = the number of sire subclasses and r_g = the computed genetic correlation.

The sampling variance for the genetic correlation coefficient $V(r_{ge})$ for Model II was approximated according to:

$$V(r_{ge}) = \frac{2\{\{1-5 + nt(1-r_g)\}\{1 + (p-1)r_g\}^2 + (p-1)r_g^2(1-t)^2\}}{(N-1)p(p-1)n^2t^2} + \frac{2r_g^2(1-t)^2}{pN(n-1)n^2t^2}$$

as presented by Robertson (1959). The additional term (;) is equal to the number of different environments (management units) involved. The

n in this instance is the average number of progeny for the sire by management unit subclasses. If the product of the intraclass correlation (t) and the average size of the related progeny subclasses (n) is greater than unity, the $V(r_{ge})$ as calculated by Robertson (1959) decreases as r_g increases. He further stated that if n becomes too large, the chance of finding an important interaction is decreased even though one exists.

Rank-order correlation coefficients and simple product moment correlation coefficients for sires between each sex (Model I) were also calculated for each dependent variable in each data set (Snedecor and Cochran, 1967). The rank order coefficient was calculated from the original rankings of the sire constants whereas the product moment coefficients were calculated from the actual sire constants.

Heritability estimates for birth weight, preweaning average daily gain and weaning weight for each model were calculated using the paternal half-sib procedure where $h^2 = \frac{4\hat{\sigma}^2_S}{\hat{\sigma}^2_T}$, (Falconer, 1960). Genetic correlations between the three traits were also calculated for each Model and data set.

Tests for the differences between the means for each data set were conducted using a modified and weighted t test described by Snedecor and Cochran (1962) for independent samples with $n_1 \neq n_2$ and $\sigma_1^2 \neq \sigma_2^2$,

RESULTS AND DISCUSSION

MODEL I

Model I was designed to evaluate the effect of the sire by sex interaction on the post-natal traits birth weight, preweaning average daily gain (ADG) and weaning weight (205-day adjusted). The interaction was examined in each of the four data sets, non-creep fed and creep fed 1/2 Simmental progeny and non-creep fed and creep fed 3/4 Simmental progeny, (NCF 1/2, CF 1/2, NCF 3/4 and CF 3/4, respectively). The overall least squares means[1] for birth weight, ADG and weaning weight for the four data sets are presented in appendix table 2.

Birth Weight. The Model I analyses of variance (table 6) showed that all sources of variation were highly significant for birth weight in all four data sets except the sex by age of dam interaction which was not significant in any of the data sets.

The differences in the mean birth weights between the four data sets (appendix table 2) revealed that there was a difference ($P<.05$) in the birth weights of the 1/2 and 3/4 Simmental calves. The 3/4 Simmental progeny were approximately 2 kg heavier at birth than the 1/2 Simmental progeny. There was no difference between the mean birth weights of the non-creep fed and creep fed progeny within the 1/2 and 3/4 Simmental calves.

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[1] The least squares means were calculated from the simultaneous solutions of the normal equations for each model and were adjusted for the disproportionality of the data with regard to the various sources of variation in the models.

TABLE 6. LEAST SQUARES ANALYSES OF VARIANCE FOR BIRTH WEIGHT (MODEL I)

	Data subset							
	NCF 1/2		CF 1/2		NCF 3/4		CF 3/4	
Source	df	M.S.[a]	df	M.S.	df	M.S.	df	M.S.
Management unit	223	102.0**	82	76.6**	562	107.4**	195	90.1**
Sire	44	58.9**	43	27.1**	44	77.6**	45	66.6**
Sex	1	1128.2**	1	211.7**	1	2802.7**	1	1171.1**
Age of dam	3	174.1**	3	42.5**	3	1236.1**	3	886.8**
Sire by Sex	42	28.1**	24	23.7**	43	27.3**	39	24.8*
Sex by Age of dam	3	8.7	3	18.2	3	11.0	3	22.2
Residual	3789	23.1	1728	9.7	7955	15.9	3746	17.0

[a] Mean Squares (kg^2).
* P<.05.
**P<.01.

The least squares means for birth weight for each sex are presented in appendix table 3. The male calves were 2.6 to 3.2 kg heavier than the female calves. This difference was similar to that reported in the literature (Laster et al., 1973; Smith et al., 1976 and Burfening et al., 1977)

The least squares means for birth weight in the 2, 3, 4 and 5 year old or older dams are presented in appendix table 4. In all four data sets the trend was for the progeny to exhibit larger birth weights as the age of the dam increases. This was especially evident between the younger ages of dam. The birth weight of calves from 2 year old dams compared across data sets were not generally different from each other except in the CF 1/2 data, where the birth weight of the progeny were approximately 2 kg lighter than the other three data sets. The birth weights of the progeny from the older dams were larger in the 3/4 Simmental calves, however. The differences between the birth weights of progeny from 2 and 3 year old dams was generally greater than the corresponding difference noted between the 4 and 5 year old or older dams within each data set. The least squares means for the birth weights of the male and female progeny for each age of dam are presented in appendix table 5.

The least squares means for birth weight for each sire in each data set are presented in appendix table 6. The significant effect of sire on birth weight was also reported by Woodward and Clark (1950),

Kress and Webb (1972) and Nunn (1974) for the beef calves in their respective studies.

The least squares means for each sex of calf within each sire are presented in appendix table 7 for each data set. The significant interaction was not in agreement with many of the reports found in the literature. Tanner et al. (1960), Wilson et al. (1969) Thrift et al. (1970) and Kress and Webb (1972) all reported that the sire by sex interacton was not a significant source of variation for birth weights of beef cattle.

Estimates of the components of variance for birth weight and the percent of the total variation for management unit, sire, the sire by sex interaction and the residual variance are presented in table 7 for Model I. The management unit component of variance for birth weight accounted for 19.5 to 28.7% of the total variance. The management unit variances for the NCF 1/2, CF 1/2 and NCF 3/4 data sets were approximately equal at 28.7, 27.1 and 28.2% of the total, respectively. The CF 3/4 management unit variance component was slightly less at 19.5% of the total variance. The environmental differences in management unit, i.e., location, management practices other than creep feeding, climate, etc., constitute an important source of variation affecting the birth weights of the progeny as evidenced by the magnitude of the variance components associated with management unit in Model I.

TABLE 7. ESTIMATES OF THE COMPONENTS OF VARIANCE AND THE PERCENT (%) EACH ARE OF THE TOTAL VARIANCE FOR BIRTH WEIGHT (MODEL I)

Data set	k_n	Management unit	k_s	Sire	k_{sx}	Sire x sex	Residual	Total
NCF 1/2	13.5	6.25 (28.7)	36.2	1.24 (5.7)	43.0	.33 (1.5)	13.90 (64.0)	21.73
CF 1/2	15.5	4.35 (27.1)	15.1	1.15 (7.2)	18.6	.75 (4.7)	9.70 (61.0)	15.97
NCF 3/4	13.9	6.55 (28.2)	92.9	.66 (2.8)	120.8	.09 (.4)	15.94 (68.8)	23.24
CF 3/4	16.5	4.43 (19.5)	46.0	1.08 (4.8)	66.1	.12 (.5)	17.04 (75.2)	22.67

The relative magnitudes of the sire variance components for birth weight were considerably less than those for management unit, (table 7). Sire components of variance accounted for 2.8 to 7.2% of the total variance in the four data sets. The sire components in the two 1/2 Semmental data sets were larger than the sire compents in the corresponding 3/4 Simmental data sets, (5.7 and 7.2% vs. 2.8 and 4.8%, respectively). The sire components of variance were also larger in the creep fed data sets than in the non-creep fed data sets, (7.2 and 4.8% vs. 5.7 and 2.8%, respectively). In all data sets, the sire variance component would indicate that the variation associated with the sire effect may be of importance in assessing the differences in birth weights of the Simmental progeny. The sire variances for birth weight reported by Cundiff et al. (1975) of 2.4% were in agreement with those of the present study.

The variance components for the sire by sex interaction (table 7) indicate that it was generally of small consequence in the explanation of the total variation of Model I. The one exception being the variation explained by the interaction in the CF 1/2 data set where it accounted for 4.7% of the total variation. This factor explains only 1.5, .4 and .5% of the total variation in the NCF 1/2, NCF 3/4 and CF 3/4 data sets, respectively. The variance components for the sire by sex interaction in the 1/2 Simmental calves did, however, contribute more to the total variation in birth weight than in the 3/4 Simmental

calves. This trend follows that reported for the sire effect. The sire by sex interaction variance components were the smallest of the three sources of variation examined.

The residual variances across the four data sets explaned 61.0 to 75.2% of the total variation examined and accounted for the largest proportion of the variation in the birth weights of the progeny for Model I. The residual variances for birth weight were larger in magnitude in the 3/4 Simmental data than they were in the 1/2 Simmental data. There appeared to be no trend in the residual variances between the creep fed and non-creep fed data within the 1/2 and 3/4 Simmental calves.

The genetic (r_{ge}) rank-order and product moment correlations of the sire's progenys performance within the two sexes for birth weight are presented in table 8. Within the NCF 1/2, NCF 3/4 and CF 3/4 data sets the genetic correlations are relatively large at .77±.13, .82±.10 and .89±.10, respectively. The genetic correlations for NCF 1/2, NCF 3/4 and CF 3/4 were an indication that there was no change in the rankings of the sires between the male and female progeny. The genetic correlation for birth weight in the CF 1/2 data was .51±.22 indicating a change in the rankings of the sires' progenys birth weights for the male and female calves. As suggested by Robertson (1959), a genetic correlation of less than .80 may be of biological importance.

The variance component for the sire by sex interaction in the CF 1/2 data set accounted for 4.7% of the total variation and supports the genetic (r_{ge}) correlation. The non-parametric rank-order correlation coefficients presented in table 8 indicate that there were few differences in the original rankings of the birth weights of the male and female progeny for the sires in the NCF 1/2 and CF 3/4 data sets. These two coefficients agree with the genetic correlations and the relative importance of the sire by sex interaction variance components. The rank-order correlation of -.14 in the CF 1/2 data set indicated that significant changes in rank were occurring between the birth weights of the male and female progeny from the various sires. The small rank-order correlation of .08 in the NCF 3/4 data set also indicated changes in rank but did not agree with the genetic correlation or the interaction variance component for the data set. The product moment correlations shown in table 8 were in close agreement with the genetic correlations. There is no evidence of a significant interaction for the birth weights between the male and female progeny in the NCF 1/2, NCF 3/4 and CF 3/4 data sets.

TABLE 8. GENETIC (r_{ge}) RANK-ORDER AND PRODUCT MOMENT CORRELATIONS OF THE SIRE'S PROGENYS PERFORMANCE WITHIN EACH SEX FOR BIRTH WEIGHT (MODEL I)

	Data set			
Correlation	NCF 1/2	CF 1/2	NCF 3/4	CF 3/4
Genetic	.77±.13	.51±.22	.82±.10	.89±.10
Rank-order	.52 (.76)[a]	-.14 (.59)	.08 (.45)	.50 (.74)
Product moment	.45 (.72)	-.03 (.52)	.33 (.64)	.52 (.76)

[a]Upper 95% confidence limit.

The significant sire by sex interaction found in three of the data sets (table 6) was not found to be an important source of variation for birth weight as evidenced by the variance components and the various correlation coefficients. In only the CF 1/2 data did the sire by sex interactions appear to be of any biological importance. The variance component explained 4.7% of the total variation in the model and the low genetic (r_{ge}) and rank-order correlations support the trend for differences in the ranking of the birth weights of the sires' male and female progeny.

Average Daily Gain. The analyses of variance under Model I (table 9) showed that all sources of variation included in the model had a significant effect on ADG except the sex by age of dam interaction in the two 1/2 Simmental data sets and the age of dam effect in the CF 1/2 data.

TABLE 9. LEAST SQUARES ANALYSES OF VARIANCE FOR PREWEANING AVERAGE DAILY GAIN (MODEL I)

	Data set							
	NCF 1/2		CF 1/2		NCF 3/4		CF 3/4	
Source	df	M.S.[a]	df	M.S.	df	M.S.	df	M.S.
Management unit	223	.204**	82	.57**	562	.195**	195	.190**
Sire	44	.036**	43	.020*	44	.060**	45	.033**
Sex	1	1.113**	1	.227**	1	2.040**	1	1.193**
Age of dam	3	.214**	3	.018	3	2.151**	3	.721**
Sire by Sex	42	.033**	24	.022**	43	.018**	39	.021**
Sex by Age of dam	3	.023	3	.014	3	.088**	3	.066**
Residual	3989	.012	1728	.012	7955	.011	3746	.011

Across data sets the mean ADG for the NCF 1/2 progeny were .03 kg per day larger than that of the CF 1/2 calves and approximately .14 kg per day smaller than the two 3/4 Simmental data sets (appendix table 2). There was no apparant difference between the ADG of the two 3/4 Simmental data sets. Within each data set the male progeny gained at a faster rate than did the female progeny (appendix table 8). The relative differences in the rate of gain between the male and female progeny within each data set was consistently between .08 and .10 kg per day. Burfening et al. (1977) reported that Simmental sired bull calves gained approximately .08 kg per day more than heifer contemporaries.

The least squares means for ADG for the different ages of dam are presented in appendix table 9. Unlike birth weight, the ADG of the progeny from 2 year old dams were less in the 1/2 Simmental calves than in the 3/4 Simmental calves. This difference remained through the mature dams. In all cases, the preweaning average daily gain of the progeny increased as the age of the dam increased from 2 to 5 years of age or older. The greatest change in ADG was between the 2 and 3 year old dams. Smith et al. (1976) and Burfening et al. (1977) reported that ADG was significantly affected by the age of the dam. Smith et al. reported that as the age of dam increased the change in ADG also increased.

The sex by age of dam interaction was not a significant source of variation in the 1/2 Simmental data but was significant in the 3/4

Simmental data. The least squares means for the sex by age of dam interaction subcells are presented in appendix table 10. In the 1/2 Simmental data the difference between the male and female progeny for ADG was the same in the younger dams as it was in the older dams. In the 3/4 Simmental data the difference in ADG between the male and female progeny from 2 and 5 year old or older dams was .01±.02 and .12±.02 kg per day, respectively. Therefore, as the age of the dam increased the average daily gain of the male calves increased over that of the female calves.

The residual correlations between birth weight and ADG are presented in appendix table 11. There was a positive but rather small correlation ($P<.05$) between birth weight and ADG in the NCF 1/2, CF 1/2 and NCF 3/4 data. There was no significant correlation between birth weight and ADG in the CF 3/4 data. The correlations indicate that the magnitude of the birth weight of the progeny does not necessarily mean that the ADG of the progeny will reflect that magnitude. The trend was especially marked in the two creep fed data sets where the correlations were less than .08. Burfening et al. (1977) reported a residual correlation between birth weight and ADG of .11 in a study with Simmental progeny pooled over different types of management. The Petty and Cartwright (1966) review reported an average phenotypic correlation of .23 between birth weight and preweaning average daily gain in beef cattle.

The genetic correlations (r_g) between birth weight and ADG of the progeny (table 11) were positive ($P<.01$) in all data sets except the

CF 1/2 data. The negative (-.38) correlation between birth weight and ADG would indicate that the genetic contribution to the birth weights and average daily gains of the calves acted in opposite directions.

The least squares means for ADG for each sire are presented in appendix table 6. The importance of sire as a source of variation for ADG was also indicated in reports by Tanner et al. (1970), Thrift et al. (1970) and Kress and Webb (1972).

The least squares means for the sire by sex interaction subcells for ADG are presented in appendix table 7. This particular source of variation was also found to have a significant effect on ADG as reported by Kress and Webb (1972) with Hereford and Angus calves. Tanner et al. (1969, 1970) and Thrift et al. (1970) did not find this interaction to be significant for ADG.

Estimates of the components of variance for ADG and their percent of the total variance for management unit, sire, the sire by sex interaction and the residual variation are presented in table 10. The variance component for management unit expressed as a percent of the total variance explained from 48 to 54% of the total variation in ADG. The effect of management unit is quite consistent across the four data sets and varys only 6% between the four data sets. The percent variation explained by management unit was almost twice as large for ADG as it was for birth weight across the four data sets. It can be seen that the prenatal development of the individual was not influenced as greatly by the

TABLE 10. ESTIMATES OF THE COMPONENTS OF VARIANCE AND PERCENT (%) EACH ARE OF THE TOTAL VARIATION FOR PREWEANING AVERAGE DAILY GAIN (MODEL I)

Data set	k_n	Management unit	k_s	Sire	k_{sx}	Sire x sex	Residual	Total
NCF 1/2	13.5	.0142 (51.8)	36.2	.0006 (1.8)	43.0	.0005 (1.8)	.0121 (44.2)	.0234
CF 1/2	15.5	.0158 (54.1)	15.1	.0005 (1.7)	18.6	.0005 (1.7)	.0124 (42.5)	.0292
NCF 3/4	13.9	.0133 (53.8)	92.9	.0005 (2.0)	120.8	.0001 (.4)	.0108 (43.7)	.0247
CF 3/4	16.5	.0109 (48.0)	46.0	.0005 (2.2)	66.1	.0002 (.9)	.0111 (48.9)	.0227

external environmental factors explained by management unit as was ADG. The estimation of the management unit variances from the study were slightly larger than those reported for herd and herd-year by Cunningham and Henderson, (1965), (15 and 18%); Sellers et al. (1970), (20 and 30%); Wilson et al. (1972), (36 to 60%); Schaeffer and Wilton (1974), (41 to 49%) and Kennedy and Henderson (1975), (25 to 41%).

The sire variance components were considerably smaller than the management unit components and were between 1.7 and 2.2% of the total variation. As with management unit, the sire components were very uniform across data sets in both absolute magnitude and percentage of the total. There were no apparant trends between creep feeding and no creep feeding or between the 1/2 and 3/4 Simmental progeny groups. The sire variance components reported for ADG were only slightly different than those reported by Cundiff et al. (1975) of 2.5% and Kennedy and Henderson (1977) of 7%. The sire variances for ADG were considerably less than they were for birth weight. This was especially true in the 1/2 Simmental data sets. The difference between sire variances for ADG and birth weight seem to indicate that the influences of sires on post-natal growth rate (ADG) were not important as they were for prenatal development (birth weight).

The sire by sex interaction variances (table 10) ranged from .4 to 1.8% of the total variances across the four data sets. The sire by sex interaction variance components within the 1/2 Simmental data were

almost identical to those for sire in the two corresponding 1/2 Simmental data sets. In the 3/4 Simmental data sets this component of variance was negligible (.4 and .9% of the total). This trend would indicate that there may be an interaction involving the sire by sex effect and the two different percentages of Simmental breeding in the progeny groups. The similarity between the percentages of variation explained by the sire and sire by sex interaction effects in the 1/2 Simmental data may indicate that the evluation of the genotype by environment interaction by sire by sex may be as important as the genotypic (sire) effect alone. The sire by sex interaction source of variation in the 3/4 Simmental data appears to be of only small consequence in relation to the total variation.

The residual variances for ADG accounted for approximately 42 to 49% of the total variation. This term was very uniform across the four data sets. The percentages of the total expressed by the residual term in the model are less for ADG than those for birth weight. The change primarily reflected the additional variance associated with the management unit term in the model.

The genetic (r_{ge}), rank-order and product moment correlations of the sires' progeny performance within the two sexes for ADG are presented in table 11. Within the NCF 3/4 and possibly the CF 3/4 data the genetic correlation is relatively large at .82±.10 and .67±.20, respectively, indicating no large interaction between sire and sex for

ADG. The genetic correlations for the NCF 1/2 and CF 1/2 data (.41±.28 and .33±.62, respectively) both indicate that there may be significant changes in the rankings of the sires' progeny for ADG between the male and female offspring.

TABLE 11. GENETIC (r_{ge}), RANK-ORDER AND PRODUCT MOMENT CORRELATIONS OF THE SIRES' PROGENYS PERFORMANCE WITHIN EACH SEX FOR PREWEANING AVERAGE DAILY GAIN (MODEL I)

	Data set			
Correlation	NCF 1/2	CF 1/2	NCF 3/4	CF 3/4
Genetic	.41±.28	.33±.63	.82±.14	.67±.20
Rank-order	.15 (.51)[a]	.47 (.78)	.28 (.60)	.17 (.52)
Product moment	.05 (.43)	.47 (.78)	.38 (.67)	.16 (.52)

[a]Upper 95% confidence limit.

The rank-order correlation indicate that within the CF 1/2 and NCF 3/4 data sets there were no significant changes in rank for ADG between the male and female progeny of the sires involved. The rank-order correlation for the NCF 1/2 and CF 3/4 data sets indicate that there may have been changes in the rankings of the male and female progeny for ADG in these two data sets.

The product moment correlations were in agreement with the rank-order correlation for all four data sets. There were apparent changes in rank and/or importance of the sire by sex interaction which is present in the NCF 1/2 data and possibly the NCF 3/4 and CF 3/4 data. The use of several different methods of evaluating the importance of

the sire by sex interaction does yield several different conclusions, i.e, the analysis of variance shows the sire by sex interaction for ADG in the CF 1/2 data to be highly significant, the variance component for the sire by sex interaction accounts for 1.7% of the total variation explained by the model, the genetic correlation shows that there is significant changes between the male and female progeny's ADG for the different sires but the rank-order and product moment correlations both show no significant changes in rank.

Weaning Weight. The Model I analyses of variance for weaning weight (table 12) shows that all sources of variation were highly significant in all four data sets except the sex by age of dam interaction in the 1/2 Simmental calves and the age of dam effect in the creep fed 1/2 Simmental data.

The least squares means for the weaning weights in the four data sets were presented in appendix table 2. There were significant differences between the weaning weights of the NCF 1/2 and the CF 1/2, NCF 3/4 and CF 3/4 data sets and between the CF 1/2 and the NCF 3/4 and CF 3/4 data sets. There was no significant difference between the two 3/4 Simmental data sets. Overall, the mean weaning weights of the 1/2 Simmental progeny were about 30 kg lighter than the 3/4 Simmental progeny. There appears to be no real biological differences between the creep fed and non-creep fed data sets within the 1/2 and 3/4 Simmental data. The trends for increased weaning weight in the 3/4

Simmental progeny follows that found for birth weight and average daily gain.

Within the four data sets the males ranged from 21.3 to 25.8 kg heavier than the female progeny (appendix table 12). The differences were in the upper range of the differences reported in the literature. Burfening et al. (1977) and Friedrich et al. (1975) both reported 19 kg differences between bull and heifer progeny from Simmental sires. The differences between the two sexes were parallel that found for average daily gain.

The least squares means for weaning weight for each age of dam are presented in appendix table 13. The trend for increased weights as the age of dam increased was noted in the weight differences between the 2 and 3 and 4 year old dams but was not as evident in the weight differences between the 4 and 5 year old and older dams. The largest increase in weaning weight was between the 2 and 3 year old dams. Across data sets the differences in weaning weights between the different ages of dams was greater in the 3/4 Simmental data sets than in the non-creep fed 1/2 Simmental data. Kress and Webb (1972) and Kress and Burfening (1972) showed that age of dam had a significant effect on weaning weight and that the peak production was at about 5 years of age. Burfening et al. (1977) reported that the differences between the 2, 3 and 4 year old dams with the 5 through 8 year old dams were 21, 8 and 0 kg, respectively, in favor of the

5 through 8 year old dams. The differences in weaning weight across ages of dam was almost parallel that of average daily gain. This was to be expected due to the very large phenotypic correlation between average daily gain and weaning weight. The weaning weights of the progeny from the mature dams (5 years of age or older) in the two 1/2 Simmental data sets were equal to or less than the weaning weights of the progeny from the 2 year old dams in the two 3/4 Simmental data sets. The weaning weights of the creep fed 1/2 Simmental data were generally less than the weaning weights of the non-creep fed 1/2 Simmental progeny for each age of dam subclass.

The sex by age of dam interaction was not a significant source of variation for the weaning weights in the two 1/2 Simmental data sets (table 12). Within the two 3/4 Simmental data sets the differences in weaning weights between the male and female progeny from the older dams were greater than that of the progeny from the younger dams (appendix table 14).

TABLE 12. LEAST SQUARES ANALYSES OF VARIANCE FOR WEANING WEIGHT (MODEL I)

	Data set							
	NCF 1/2		CF 1/2		NCF 3/4		CF 3/4	
Source	df	M.S.[a]	df	M.S.	df	M.S.	df	M.S.
Management unit	223	932.7**	82	11105.8**	562	8783.6**	195	8490.8**
Sire	44	1769.4**	43	816.9*	44	3000.5**	45	1653.3**
Sex	1	62554.8**	1	12644.0**	1	119251.8**	1	66490.0**
Age of dam	3	11409.5**	3	1092.1	3	112883.4**	3	41321.5**
Sire by Sex	42	1527.3**	24	936.1*	43	887.9**	39	920.0**
Sex by Age of dam	3	956.4	3	790.9	3	3790.5**	3	3296.9**
Residual	3789	546.3	1728	542.1	7955	488.8	3746	492.9

[a] Mean squares (kg^2)

* P<.05.

**P<.01.

The residual correlations prsented in appendix table 11 indicated that the phenotypic correlations between preweaning average daily gain and weaning weight are almost unity (.98 to .99). This correlation was quite high due to the part-whole relationship between the two triats. The correlations between birth weight and weaning weight ranged from .21 to .29. Across the four data sets the correlation between birth weight and weaning weight in the non-creep fed data were higher than the corresponding correlation for the creep fed data. These correlations were, however, not different between the 1/2 and 3/4 Simmental data sets. The correlations would suggest that the utilization of creep feeding by the 1/2 or 3/4 Simmental progeny resulted in a slightly reduced correlation between the birth weight and weaning weight of the progeny involved. This difference however was not major enough to warrant extreme concern over this trend. The review conducted by Petty and Cartwright (1966) showed that the average correlation between ADG and weaning weight was approximately .97 and for birth weight and weaning weight it was .39.

The individual least squares means for weaning weight for each sire are presented in the appendix table 6. The reports in the literature also show sire to be a significant source of variation for weaning weight, (Pahnish et al.,1961; Wilson et al., 1969; Kress and Webb, 1972 and Nunn, 1974).

The significant sire by sex interaction in each of the four data sets was consistant with the reports by Wilson et al. (1969) and Kress and Webb (1972). The least squares means for weaning weight for each sire by sex subclass is presented in appendix table 7. Kress and Webb (1972) indicated that the particular sire by sex interaction in their study was an important source of variation for weaning weight due to the difference in the rankings of the particular sires for the different sexes.

Estimates of the variance components for weaning weight and their percent of the total variation for management unit, sire, the sire by sex interaction and the residual variation are presented in table 13.

The management unit variance components across the four data sets ranged from 48.0 to 53.9% of the total variation. The variances associated with the different management practices would appear to be very important in the explanation of the total variation associated with weaning weight under Model I. The variance components for management unit was also quite consistent across the four data sets. As with birth weight, the management unit variances for ADG constitute a major portion of the variation explained by Model I.

TABLE 13. ESTIMATES OF THE COMPONENTS OF VARIANCE AND PERCENT (%) EACH ARE OF THE TOTAL VARIATION FOR WEANING WEIGHT (MODEL I)

Data set	k_n	Management unit	k_s	Sire	k_{sx}	Sire x sex	Residual	Total
NCF 1/2	13.5	650.0 (51.9)	36.2	33.7 (2.7)	43.0	22.8 (1.8)	546.3 (43.6)	1252.8
CF 1/2	15.5	680.3 (53.9)	15.1	18.2 (1.4)	18.6	21.2 (1.7)	542.1 (43.0)	1262.7
NCF 3/4	13.9	595.1 (53.4)	92.9	27.0 (2.4)	120.8	3.3 (.3)	488.8 (43.9)	1114.2
CF 3/4	16.5	484.7 (48.0)	46.0	25.2 (2.5)	66.1	6.5 (.6)	492.9 (48.8)	1009.3

The percent variation explained by the sire effect were considerably less than those for management unit. These percentages ranged from 1.4 to 2.7% of the total. These sire variances were similar to those reported by Cundiff et al. (1975) of 1.2% and Kennedy and Henderson (1977) of 3% of their respective total variances.

The sire by sex interaction variances for the four data sets (table 13) were small and ranged from .3 to 1.8% of the total variance. The sire by sex interaction variance components within the 1/2 Simmental data were similar in magnitude to the corresponding sire variance components. The sire by sex interaction variance components for weaning weight in the 3/4 Simmental data sets were essentially a negligible portion (.3 and .6%) of the total variation. The sire by sex interaction variances for weaning weight were the smallest of the three sources of variation examined.

The residual variances across the four data sets accounted for 43.0 to 48.8% of the total variation. The residual variances and the management unit variances were similar in magnitude.

The genetic correlations between ADG and weaning weight for Model I were between .97 and .99. These correlations were not unlike the residual correlation between ADG and weaning weight. The genetic correlations between birth weight and weaning weight were between .54 and .65 in the NCF 1/2, NCF 3/4 and CF 3/4 data sets, but were negative (-.16) in the CF 1/2 data set.

The genetic (r_{ge}) rank-order and product moment correlation coefficients of the sire's progenys performance within the two sexes for weaning weight are presented in table 14. Within the two 3/4 Simmental data sets the genetic correlations were relatively large at .88±.10 and .77±.17. These correlation coefficients indicated that for weaning weight there was no biologically important interaction between the sire's progeny within the two sexes. The two genetic correlations for the NCF 1/2 and CF 1/2 data sets (.49±.24 and .27±.52, respectively) both indicated that there may have been significant changes in the rankings of the sire's progeny between the bulls and heifers for weaning weight.

The variance components for the sire by sex interaction were also larger in the two 1/2 Simmental data sets but did not indicate any real strong biological value of this effect for weaning weight. The percent variation for the two 3/4 Simmental data sets are essentially zero and did agree with the genetic correlations.

Examination of the nonparametric rank-order correlations suggested several different interpretations of the sire by sex interaction for weaning weight. The rank-order coefficients of correlation for the CF 1/2 data set indicated that there was no changes in the rankings of the sires in the male and female progeny for weaning weight. Within the NCF 1/2, NCF 3/4 and CF 3/4 data sets the rank-order correlation coefficients of .18, .29 and .23, respectively, suggested that some

TALBE 14. GENETIC (r_{ge}) RANK-ORDER AND PRODUCT MOMENT CORRELATIONS OF THE SIRE'S PROGENYS PERFORMANCE WITHIN EACH SET FOR WEANING EIGHT (MODEL I)

Correlation	NCF 1/2	CF 1/2	NCF 3/4	CF 3/4
Genetic	.49±.24	.27±.52	.88±.10	.77±.17
Rank-order	.18 (.53)[a]	.42 (.76)	.29 (.61)	.23 (.56)
Product moment	.16 (.52)	.41 (.75)	.37 (.66)	.21 (.55)

[a]Upper 95% confidence limit.

changing in the ranking of the sires was taking place between the weaning weights of the male and female progeny. The product moment correlations were in close agreement with the rank-order correlations. The three correlations within the NCF 1/2 data agree with each other. In the NCF 1/2 data they suggest that significant changes in ranking of the sires was present between the bull and heifer weaning weights and in the NCF 3/4 data the opposite trend was indicated. The rank-order and product moment correlations did not agree with the genetic correlations in the CF 1/2 data set.

The heritability estimates for birth weight, preweaning average daily gain and weaning weight for the four data sets are presented in table 15. The heritability estimates of .23±.06 and .29±.03 for birth weight within the two data sets for the 1/2 Simmental progeny and .19±.05 in the CF 3/4 data set were smaller than the average reported by Petty and Cartwright (1966) of .44. The estimate of .11±.08 for

the NCF 3/4 data is smaller than the other three estimates and was due to the small sire variance component within the data set for this trait (table 7).

The heritability estimates for preweaning average daily gain were considerably smaller than those reported by Petty and Cartwright (1966) where .26 was the average of the beef cattle studies they reviewed. These estimates were however, only slightly smaller than the estimates of .10±.10 reported by Cundiff et al. (1975) which were computed from a within herd analysis.

TABLE 15. HERITABILITY ESTIMATES FOR BIRTH WEIGHT, PREWEANING AVERAGE DAILY GAIN (ADG) AND WEANING WEIGHT (MODEL I)

	Data set	
Trait	NCF 1/2	CF 1/2
Birth weight	.23±.06	.29±.03
ADG	.09±.04	.07±.03
Weaning weight	.11±.04	.06±.04
	NCF 3/4	CF 3/4
Birth weight	.11±.08	.19±.05
ADG	.08±.05	.09±.04
Weaning weight	.10±.05	.10±.04

Heritability estimates for weaning weight were .11±.04, .06±.04, .10±.05 and .10±.04 for the NCF 1/2, CF 1/2, NCF 2/4 and CF 3/4 data sets, respectively. These estimates were less than the average of .31 reported by Nelsen (1976) and .28 reported by Petty and Cartwright (1966).

Model II

Model II was designed to evaluate the effect of the sire by management unit interacton on birth weight, preweaning average daily gain and weaning weight. The interaction was examined in two non-creep fed sets of data comprised of 1/2 and 3/4 Simmental progeny. The overall least squares means for birth weight, ADG and weaning weight are presented in appendix table 15. These means were not drastically different from those reported for Model I within the corresponding two data sets. As under Model I the 1/2 Simmental calves were lighter at birth, gained less per day and were lighter at weaning than the 3/4 Simmental calves.

Birth Weight. The analyses of variances for birth weight (Model II) are presented in table 16. All sources of variation had a significant effect on the birth weights of the two progeny groups except the sex by age of dam interaction in both data sets and the sire by management unit interaction in the 1/2 Simmental data set.

The least squares means for the sex, age of dam and the sex by age of dam interaction effects for birth weight are presented in appendix tables 16 and 18. The trends evidenced by these means were not different from those reported for these effects under Model I.

TABLE 16. LEAST SQUARES ANALYSES OF VARIANCE FOR BIRTH WEIGHT MODEL II

	Data set			
	NCF 1/2		NCF 3/4	
Source	df	M.S[a]	df	M.S.
Management unit	24	148.3**	84	186.2**
Sire	44	33.3[b]*	44	60.6**
Management unit by sire	23	15.7	253	25.2**
Sex	1	1020.0**	1	1502.4**
Age of dam	3	124.1**	3	350.9**
Sex by Age of dam	3	4.9	3	24.9
Residual	969	18.8	2989	15.7

[a]Mean square (kg^2)
[b]Tested with the management unit by sire interaction M.S.
* P<.05.
**P<.01.

The effect of sire on the birth weights of the 1/2 and 3/4 Simmental calves under Model II was significant and the means for the birth weights of the progeny from each sire are presented in appendix table 19.

Estimates of the components of variance and the percent of the total variance for management unit, sire, the sire by management unit interaction and the residual variance are presented in table 17 for Model II.

TABLE 17. ESTIMATES OF THE COMPONENTS OF VARIANCE AND THE PERCENT (%) EACH IS OF THE TOTAL VARIANCE FOR BIRTH WEIGHT (MODEL II)

Source	Data set			
	k	NCF 1/2	k	NCF 3/4
Management unit	7.6	11.03 (34.7)	12.3	4.95 (20.5)
Sire	14.3	1.93 (6.1)	47.6	.93 (3.9)
Management unit by sire	4.3	-.74 (0.0)	6.0	1.58 (6.6)
Residual		18.84 (59.2)	16.66	(69.1)
Total		31.80	24.12	

The management unit component of variance for birth weight was 15% larger in the 1/2 Simmental data than in the 3/4 Simmental data 35 vs. 20%, respectively). This source of variation appeared to be of major importance in the explanation of the total variance associated with Model II.

The sire variance associated with birth weight under Model II explained 6.1 and 3.9% of the total variation in the 1/2 and 3/4 Simmental data sets, respectively. These variances were slightly larger than those reported by Cundiff et al. (1966) of 2.4% of the total variation.

The sire by management unit interaction component of variance for birth weight in the 1/2 Simmental data was less than zero. Theoretically, a component of variance cannot be negative and is therefore assumed to be negligible and thus accounts for none of the variation in the model. The sire by management unit interaction explained 6.6% of the total variation in the 3/4 Simmental data set.

The residual variances were the largest of the variances examined under Model II at 59.2 and 69.1% of the total for the 1/2 and 3/4 Simmental progeny groups, respectively.

The genetic correlations of the sire's progeny performance in the different management units are presented in table 18. The genetic correlation for the 1/2 Simmental data is not available due to the small but negative sire by management unit interaction variance

component. The genetic correlation (r_{ge}) of .37±.36 for the birth weights of the 3/4 Simmental data set would indicate that the sire rankings for birth weight within each management unit is not the same across management units. The small genetic correlation would indicate that the significant sire by management unit interaction may be of real biological value and important in the evaluation of different sires for birth weight within different management units.

TABLE 18. GENETIC CORRELATIONS (r_{ge}) OF THE SIRES' PROGENYS PERFORMANCE WITHIN THE DIFFERENT MANAGEMENT UNITS FOR EACH TRAIT (MODEL II)

	Data set	
	NCF 1/2	NCF 3/4
Birth wt	---[a]	37±.36
Average daily gain	---	.53±.50
Weaning wt	---	.53±.54

[a]Not calculated due to negative management unit by sire interaction variance component.

Average Daily Gain. The analyses of variance for preweaning average daily gain under Model II are presented in table 19. All sources of variation included in the model were significant except the sire and the sire by management unit interaction effects in the 1/2 Simmental data set.

TABLE 19. LEAST SQUARES ANALYSES OF VARIANCE FOR PREWEANING AVERAGE DAILY GAIN (MODEL II)

Source	Data set NCF 1/2 df	NCF 1/2 M.S.[a]	NCF 3/4 df	NCF 3/4 M.S.
Management unit	24	.401**	84	.353**
Sires	44	.026[b]	44	.057**
Management unit by sire	23	.014	253	.017**
Sex	1	.879**	1	1.211**
Age of dam	3	.083**	3	.727**
Sex by Age of dam	3	.060**	3	.044**
Residual	969	.014	2989	.012

[a] Mean square (kg^2).
[b] Tested with the management unit by sire interaction M.S.
**P<.01.

The least squares means for ADG for the effect of sex, age of dam and the sex by age of dam interaction are presented in appendix table 20 to 22. The means were not different from those reported in the Model I analyses.

The residual correlation between birth weight and ADG in appendix table 23 indicated that as an individuals birth weight increased so did its ADG. This was noted in both the 1/2 and 3/4 Simmental data sets. The correlation and slightly larger in the 1/2 Simmental data (.23) than in the 3/4 Simmental data (.13). The genetic (r_g) correlations between birth weight and average daily gain in the 1/2 and 3/4 Simmental progeny groups were .55 and .33, respectively.

The least squares means for average daily gain for each sire under Model II are presented in appendix table 19.

Estimates of the variance components and their percent of the total variation for management unit, sire, the sire by management unit interaction and the residual variances are presented in table 20.

The variance components for management unit under Model II explained 68.7% of the total variation in ADG in the 1/2 Simmental data sets and 44.9% of the total variation in the 3/4 Simmental data set. The management unit source of variation within the two data sets, as in Model I, would appear to explain a large portion of the variance associated with the preweaning average daily gain of the progeny.

TABLE 20. ESTIMATES OF THE COMPONENTS OF VARIANCE AND THE PERCENT (%) EACH IS OF THE TOTAL VARIANCE FOR PREWEANING AVERAGE DAILY GAIN (MODEL II)

Source	Data set			
	k	NCF 1/2	k	NCF 3/4
Management unit	7.6	.0330 (68.7)	12.3	.0109 (44.9)
Sire	17.3	.0008 (1.7)	47.6	.0009 (3.7)
Sire by Management unit	4.3	-.0001 (0.0)	6.0	.0008 (3.3)
Residual		.0142 (29.6)		.0117 (48.1)
Total		.0480		.0243

The estimate of the sire component of variance for ADG was much smaller than the management unit component and was smaller in the 1/2 Simmental data than in the 3/4 Simmental data (1.7 vs. 3.7%, respectively). The small sire variance for the 1/2 Simmental data set was in support of the nonsignificant effect of sire in the analyses of variance, (table 19). It should be noted that the absolute magnitude of the sire variance component for both data sets was approximately the same.

The sire by management unit interaction component for ADG as with birth weight was negative in the 1/2 Simmental data. It was assumed to contribute nothing to the total variation in the model. The sire by management unit interaction variance component in the 3/4 Simmental

data set explained 3.3% of the total variation in Model II and was similar in magnitude to the sire component. It is possible to assume that the sire by management unit interaction may be of biological importance in the variation of ADG.

The residual variances for ADG in Model II explained 29.6 and 48.1% of the total variances of the 1/2 and 3/4 Simmental data, respectively.

The genetic (r_{ge}) correlation of the sire's progenys performance in the different management units (table 18) were not calculated for the 1/2 Simmental data due to the negative component of variance associated with the sire by management unit interaction. This correlation was .53±.50 for the 3/4 Simmental data. The correlation agrees with the significant interaction in the analyses of variance and the magnitude of the variance component associated with this effect.

Weaning Weight. The analyses of variance for weaning weight for the 1/2 and 3/4 Simmental data sets are presented in table 21. All sources of variation were significant for weaning weight except the sire by management unit interaction effect in the 1/2 Simmental data set.

The least squares means for sex, age of dam and the sex by age of dam interaction are presented in appendix table 24 to 26. The means and trends evidenced for these effects were the same as those outlined for Model I. The residual correlations of birth weight with weaning

TABLE 21. LEAST SQUARES ANALYSES OF VARIANCE FOR WEANING WEIGHT (MODEL II)

	Data set			
	NCF 1/2		NCF 3/4	
Source	df	M.S.[a]	df	M.S.
Management unit	24	10973.0**	84	15688.3**
Sire	44	1241.9[b]*	44	2646.1**
Management unit by sire	23	608.6	253	762.3**
Sex	1	50301.4**	1	69553.3**
Age of dam	3	4898.4**	3	37159.6**
Sex by Age of dam	3	2693.8**	3	2076.5**
Residual	969	661.9	2989	528.3

[a] Mean square (kg^2).
[b] Tested with the management unit by sire interaction M.S.
* P<.05.
**P<.01.

weight were approximately .30 and .39 and between ADG and weaning weight they were .99 in both data sets. The correlations indicate that there were positive and significant relationships between the growth traits.

The least squares means for the weaning weights of the progeny for each sire are presented in appendix table 19. The sire by management unit interaction was not significant in the 1/2 Simmental data set but was significant in the 3/4 Simmental data set which was the case for both birth weight and ADG as well.

Estimates of the components of variance and the percent each was the total for the management unit, sire, the sire by management unit interaction and residual are presented in table 22. The management unit variance component explained 69.1 and 44.1% of the total variance for weaning weight in the 1/2 and 3/4 Simmental data, respectively, under Model II. The sire component accounted for 1.8 and 4.0% of the variation for weaning weight in the 1/2 and 3/4 Simmental data, respectively (table 22).

As with the birth weight and ADG traits, the sire by management unit interaction variance component was negative in the 1/2 Simmental data. The sire by management unit interaction explained 3.6% of the total variance for weaning weight in the 3/4 Simmental data set and was almost as large as the sire variance component.

TABLE 22. ESTIMATES OF THE COMPONENTS OF VARIANCE AND THE PERCENT EACH ARE OF THE TOTAL VARIANCE FOR WEANING WEIGHT (MODEL II)

Source	Data set			
	k	NCF 1/2	k	NCF 3/4
Management unit	7.6	1568.9 (69.1)	12.3	482.1 (44.1)
Sire	14.3	40.5 (1.8)	47.6	44.1 (4.0)
Sire by Management unit		-12.4 (0.0)	6.0	38.9 (3.6)
Residual		661.9 (29.1)		528.3 (48.3)
Total		2271.3		1093.4

The residual variances for weaning weight explained 29.1 and 48.3% of the total variance for the 1/2 and 3/4 Simmental data sets, respectively.

The genetic correlations of the sire's progenys performance in the different management units for weaning weight are presented in table 18. The genetic correlation for the 1/2 Simmental data is not available due to the negative sire by management unit interaction variance component. The estimate of .53±.54 for weaning weight in the 3/4 Simmental data would indicate that the sire rankings for the weaning weights of the sire's progeny were not the same in the different management units.

The heritability estimates for birth weight, average daily gain and weaning weight for the two data sets are presented in table 23. The heritability estimates for birth weight within the two data sets were .24±.08 and .15±.05 and similar to the estimates obtained from Model I. The heritability estimates for ADG were .07±.08 and .15±.06 and for weaning weight they were .07±.08 and 16±.06 for the 1/2 and 3/4 Simmental progeny groups, respectively. The lower heritability estimates for the 1/2 Simmental data were similar to those in Model I. The estimates for the 3/4 Simmental data were larger in Model II than in Model I.

TABLE 23. HERITABILITY ESTIMATES FOR BIRTH WEIGHT, PREWEANING AVERAGE DAILY GAIN (ADG) AND WEANING WEIGHT (MODEL II)

Trait	Data set	
	NCF 1/2	NCF 3/4
Birth wt	.24±.08	.15±.05
Average daily gain	.07±.08	.15±.06
Weaning wt	.07±.08	.16±.06

The genetic correlation (r_g) between birth weight and weaning weight was .66 and .45 in the 1/2 and 3/4 Simmental data, respectively. The genetic correlations between ADG and weaning weight were both .99 in Model II (table 23).

Discussion

Examination of the absolute values for the management unit variance components across data sets in the present study indicated that the management unit variances for the creep fed 3/4 Simmental progeny may have been slightly smaller than the management unit variances for the non-creep fed 3/4 and 1/2 Simmental progeny. It seems unlikely that the practice of subsequent creep feeding or not creep feeding of the progeny would have an effect on the variance components for management unit for the birth weight of those progeny. It is, however, possible to theorize that a particular management technique such as creep feeding, a more ambitious management technique, may be associated with other management practices which may in themselves be on a more intensified basis. The management units involved with creep feeding may therefore be more uniform in nature across the populations involved. If the management units which utilize creep feeding and other positive management techniques are producing progeny more uniform in terms of the performance traits being examined then the variation in the performance of the progeny could be reduced. This could have resulted in the lower management unit variance components for the creep fed 3/4 Simmental data set.

The lack of a sufficient decrease in the variance component for management unit for the creep fed 1/2 Simmental data set based on the above mentioned theory would indicate that other factors also play

a role in the responses of the progeny across various management techniques. The primary difference between the 1/2 and 3/4 Simmental progeny is the breeding of the dam. The 1/2 Simmental calves are all from dams with non Simmental backgrounds while the 3/4 Simmental calves are from dams which are 1/2 Simmental themselves. The general genotypic background of the calves or the lack of a common genetic background as in the 1/2 Simmental calves may result in increased variation associated with the management units in the two 1/2 Simmental data sets when compared to the two 3/4 Simmental data sets.

An increased heterotic advantage in the two 1/2 Simmental data sets may result in more diversified responses and thus the larger absolute measure of variation associated with management unit in the 1/2 Simmental data. This trend was especially noted in Model II where the management unit variance components were considerably smaller for the 3/4 Simmental data than the 1/2 Simmental data.

The relative magnitudes of the sire variance components for the birth weight of the calves suggested that the variation associated with the sires may have been larger in the 1/2 Simmental calves than in the 3/4 Simmental calves. This difference may have been due to the differences in the background of the calves (non Simmental vs. 1/2 Simmental dams) or to the differences in the types of sires used in the data sets. The 1/2 Simmental data sets contain many of the original

foundation cows and the sires used were bred at random without regard to any previous knowledge about the sire. The 3/4 data sets contain the progeny from subsequent breedings and the sires used had some data available in the form of sire summaries and therefore may not have been bred at random.

The sire variances in relation to those for birth weight would suggest that there is less variation between sires during the postnatal growth period. The management unit variances are also larger for the postnatal growth traits and may indicate that the postnatal development of the calf was more influenced by the environment than the genotype during the prenatal development. The possibility of selected matings being practiced in the 1/2 Simmental data in more recent years such as grouping of dams by size for certain sire groups may have had an influence on the overall variation in birth weight but may not have been as evident in the subsequent growth. If small dams were mated to sires with less calving difficulty or smaller birth weights in certain instances there may be some changes in the variation exhibited across the data sets. The postnatal growth may then be less variable and more uniform across sires regardless of type of dam. The smaller sire variances for birth weight in the 3/4 Simmental data compared to the 1/2 Simmental data may have been a result of the birth weights being less variable in part due to the overall maximization of the birth weights of the calves in the 3/4 Simmental data since they

are all from 1/2 Simmental dams and presumably of more uniform size and type. The influences of heterosis discussed earlier may also play a role in the assessment of the differences in the variation of the birth weights of the 1/2 and 3/4 Simmental calves.

The variation of the genotype of environment interaction of sire by sex shows two distinct trends in the performance traits examined. The 1/2 Simmental data sets exhibit a marked increase in the amount of variation explained by the interaction for all three traits over the 3/4 Simmental data. The variation associated with the interaction in the 3/4 Simmental data sets is almost zero and therefore could be considered to be of little or no importance in the assessment of the performance traits in these data sets. The genetic correlations and rank-order correlations generally indicate that the significant interaction of sire by sex may be of biological importance. These coefficients were less than unity and suggested that there were changes in the rankings of the sires for the different sexes in the production traits examined.

Within the 1/2 Simmental data there may need to be a more detailed examination of the performance of the progeny based on the magnitude of the interaction variance components and genetic correlations. The performance of an individual as measured by the preweaning traits appears to be influenced by not only the traditional effects of genotype (sire) and environment (sex) but also the

interaction of the genotype by environment (sire by sex). The possibility of an important genotype by environment interaction of this type could be valuable in the utilization of the genotype (sires) and may require some changes in the present progeny testing programs as well. The present method of performance testing sires with the progeny he produced is generally done on the steer progeny in feed trials or some similar manner. If the sire by sex interaction was important then the need for evaluation of both sexes would be important. It would seem possible that the sire by sex interaction may play an important role in the future of the beef cattle industry.

The magnitude of the variance components for the genotype by environment interaction of sire by management unit in Model II suggests that in the 3/4 Simmental data it is an important source of variation for birth weight and preweaning growth. It would appear that the future evaluation of the performance of the progeny across different management units may require the examination of the interaction of sire with management unit. The classification of environments in terms of management unit in the present study lacks the precision and distinctness one might expect to utilize in a controlled experiment. The peculiarities of the individual management units in terms of management technique and external environmental influences are not known in this particular study. The major classification of

creep or no creep feeding may be in question as well. It was not known exactly what type, how much, when administered or length of administration of the creep feeding were met by the individual management units designated as being creep fed in the data base.

A conclusion that the sire by management unit interaction is of major importance could be misleading due to some unanswered and uninvestigated circumstances which may be present in the data. One such consideration is the possible effect of regional differences in the data. The data does contain progeny from herds located throughout the United States. The availability of semen for a particular sire may also dictate the type of herd in which he was utilized. These and other situations may play a role in the evaluation of the genotype by environment interactions such as sire by management unit as they may have an important influence on the variances associated with the interactions.

SUMMARY

Field records supplied by the American Simmental Association from the 1976 sire evaluation program were used in this study. The data represented approximately 350,000 progeny from more than 700 purebred Simmental sires used in herds located throughout the United States. The data were edited for records without actual birth weight, weaning weight, birth date of the dam or with age at weaning outside the range of 160 to 250 days of age. Only 1/2 and 3/4 Simmental calves were retained. Steer data was removed due to a lack of adequate numbers. Management unit was designated as weaning weight data within breeder number and accounted for herd, year and season of birth in the analyses.

The data were then subdivided into four data sets. The four data sets were creep fed 1/2 and /34 Simmental (CF 1/2 and CF 3/4, respectively).

The four data sets were analyzed separately using mixed model least squares analyses of variance procedures outlined by Harvey (1972), and contained 1,885, 4,033, 4.106 and 8,612 progeny form 44, 46, 45 and 45 sires for the CF 1/2, CF 3/4, NCF 1/2 and NCF 3/4 data, respectively.

Two models were used to analyze the effects of environmental and genetic sources of variation and interactions associated with the dependent variables birth weight, preweaning average daily gain (ADG) and weaning weight. Model I was used to evaluate the effect of the

sire by sex interaction within the four data sets. Model II was used to evaluate the sire by management unit interaction in the non-creep fed data sets.

Variance components for the random management unit effect and the sire and sire by sex and sire by management unit interactions were calculated from the analyses. Genetic correlations of the sire's progenys performance within each sex or management unit were also calculated. Heritabilities were calculated from Models I and II using the paternal half-sib procedure.

Under Model I, all sources of variation were significant for birth weight ADG and weaning weight except the sex by age of dam interaction. Only ADG and weaning weight in the NCF 3/4 and CF 3/4 were significantly affected by the sex by age of dam interaction. With Model II all sources of variation were significant except sex by age of dam for birth weight and the management unit by sire interactions in the NCF 1/2 data set.

The percentage of the total variation accounted for by management unit components of variance for the four populations from Model I ranged from 19.5% to 28.7% for birth weight and 48% to 519% for weaning weight. The differences in management unite, i.e., location, climate, management techniques, etc., constitute an important source of variation affecting the performance of the progeny involved. Management unit variances for ADG and weaning weight were about twice

as important as those for birth weight. This increase in the relative variances was probably a result of more diversified post-natal management practices within the management units involved.

Sire components of variance ranged from 1.4 to 7.2% of the total variation. Across populations the sire components for the 3/4 Simmental data for birth weight were about half as large as the 1/2 Simmental data. For ADG and weaning weight there was less variability among populations than for birth weight. The percentages of variation associated with sire for ADG and weaning weight ranged from 1.4 to 2.7% of the total. The trend exhibited between the 1/2 and 3/4 Simmental populations reported for birth weight was not present in the ADG and weaning weight traits. The CF 1/2 Simmental population had the smallest single percent at approximately 1.5% which was opposite to the birth weight trait where it was the largest single percent at 7.2% of the total. The sire components of variance for birth weight would appear to be of some importance. Trends for larger variances associated with the 1/2 Simmental data may have been indicative of an increased response in birth weight due to the effects of heterosis. It was not determined whether or not this difference in sire variances for percentage of Simmental in the populations was and indication of a genotype-environment interaction of sure by percent Simmental or due to simpling.

Although a significant source of variation, the sire by sex

variance components for birth weight, ADG and weaning weight were smaller than those for sire. The sire by sex components were between .4 and 1.5% of the total for birth weight and between .3 and 1.4% of the total for ADG and weaning weight. The differences between the 1/2 and 3/4 Simmental may indicate a genotype by environment interaction of the sire by sex effect across the two different percentages of Simmental breeding in the progeny groups analyzed.

The genetic correlations for birth weight were consitently large (>.75) except in the creep fed 1/2 data indicating that no changes in rank were occurring between the birth weights of the male and female progeny of the sires analyzed. The lower correlation (.51±.22) in the creep fed 1/2 data may indicate some changes in rank for the sires in this data set. The correlations for weaning weight and ADG indicated that the 1/2 Simmental progeny may contain significant changes in sire rankings between the sexes (correlations >.50) whereas the 3/4 Simmental data sets did not exhibit this trend (correlations >.75).

The heritability estimates for birth weight were .23, .29, .11 and .19; for ADG they were .09, .07, .08 and .09; and for weaning weight they were .11, .06, .10 and .10 for NCF 1/2, CF 1/2, NCF 3/4 and CF 3/4, respectively. The heritability estimates for the traits analyzed were somewhat lower than those generally reported.

The management unit components of variance from Model II for birth weight were 15% larger in the 1/2 Simmental data than in the

3/4 Simmental data (35 vs. 20%). The sire component of variance was also larger in the 1/2 Simmental data (6 vs. 4%) and the management unit by sire interaction variance component was negative in the 1/2 Simmental population and was 7% of the total for the 3/4 Simmental population. Management unit variance components for weaning weight were 69% and 44% for the 1/2 and 3/4 data, respectively. Sire components of variance for weaning and ADG were a small percent of the total variance examined in the two populations, however, this component was larger in the 3/4 Simmental population than in the 1/2 Simmental population (4 vs. 2%, respectively). The management unit by sire interaction component for ADG and weaning weight was negative for the 1/2 Simmental data and approximately 4% of the total in the 3/4 Simmental data. The difference in the size of the management unit variances between the 1/2 and 3/4 Simmental data sets under Model II may have been due to the effects of the heterosis mentioned earlier.

The genetic correlations of the 1/2 Simmental populations were not estimated due to the small but negative estimate of the sire by management unit variance component. The relatively low correlations in the three traits within the 3/4 Simmental population indicated that the rankings of the sires within the different management units was not the same across the different management units.

The heritability estimates from Model II for birth weight were similar between the 1/2 and 3/4 Simmental data sets at .14 and .16, respectively. The heritability estimates for weaning weight and ADG were lower in the 1/2 Simmental data than in the 3/4 Simmental data, .06, .15 and .07, .16, respectively. As with Model I these heritability estimates were lower than those generally reported.

LITERATURE CITED

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Anderson, D. G. and C. C. O'Mary. 1974. Preweaning traits of some exotic beef crosses. Proc. West. Sec. Am. Soc. Anim. Sci. 25:1.

Bailey, C. M., J. A. Edwards and Y. O. Koh. 1977. Cross between mildly inbred Hereford selection lines of common genetic origin. J. Anim. Sci. 44:23.

Barlow, R. E., Belinda Dettmann and L. G. Williams. 1974. Non-genetic factors affecting weaning performance of Angus cattle in N.S.W. Proc. Aust. Soc. Anim. Prod. 10:37.

Bellows, R. A., R. E. Short, D. C. Anderson, B. W. Knapp and O. F. Pahnish. 1971. Cause and effect relationships associated with calving difficulty and calf birth weight. J. Anim. Sci. 33:407.

B.I.F. 1976. Guidelines for uniform beef improvement programs. U.S.D.A. Extension Service. Program Aid 1020.

Bovard, K. P., B. M. Priode and W. R. Harvey. 1963. Estimates of year, sex, age of dam, age and inbreeding effects on beef calf performance to weaning. J. Anim. Sci. 22:244 (Abstr.).

Bradley, No. W., L. V. Cundiff, J. D. Kemp and T. R. Greathouse. 1966. Effects of sex and sire on performance and carcass traits of Hereford and Hereford-Red Poll calves. J. Anim. Sci. 25:783.

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

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

Brinks, J. S., R. T. Clark, N. M. Kieffer and J. J. Urick. 1964. Estimates of genetic environmental and phenotypic parameters in range Hereford females. J. Anim. Sci. 23:711.

Brinks, J. S., R. T. Clark and N. M. Kieffer. 1965. Evaluation of response to selection and inbreeding in a closed line of Hereford cattle. U.S.D.A. Tech. Bull. 1323.

Brinks, J. S., J. J. Urick, O. F. Pahnish, B. W. Knapp and T. M. Riley. 1967. Heterosis in preweaning and weaning traits among lines of Hereford cattle. J. Anim. Sci. 26:278.

Brinks, J. S., B. W. Knapp, J. J. Urick and O. F. Pahnish. 1972. Heterosis in preweaning maternal traits among lines of Hereford cattle. J. Anim. Sci. 34:14.

Brinks, J. S. and B. W. Knapp. 1975. Effects of inbreeding on performance traits of beef cattle in the western region. Colo. State Univ. Exp. Sta. West. Reg. Tech. Bull. 123.

Brown, C. J., C. A. Baugus and S. Sabin. 1961. Evaluation of factors affecting the growth of spring lambs. Ark. Agr. Exp. Sta. Bull. 646.

Brumby, P. J. 1961. The causes of differences in production between dairy herds. Anim. Prod. 3:277.

Burdick, J. M. and L. D. McGilliard. 1963. Interactions between sires in artificial insemination and management of dairy herds. J. Dairy Sci. 46:452.

Burfening, P. J. and D. D. Kress. 1973. Heterosis for most probable producing ability in Hereford cows. J. Anim. Sci. 36:7.

Burfening, P. J., D. D. Kress, R. L. Friedrich and D. Vaniman. 1977. Calving difficulty and growth rate of Simmental sired calves. I. Factors affecting calving difficulty and growth rate. (In Press).

Burfening, P. J., D. D. Kress, R. L. Friedrich and D. Vaniman. 1977. Calving difficulty and growth rate of Simmental sired calves II. Genetic parameter estimates. (In Press).

Burnside, E. B., G. K. MacLeod and D. G. Grieve. 1969. Genotype and environment in calf production. Anim. Prod. 11:285. (Abstr.).

Burnside, E. B., T. R. Batra, G. K. MacLeod and D. G. Grieve. 1972. Genotype-environment interaction in calf production. I. Growth traits. J. Anim. Sci. 35:317.

Burris, M. J. and C. T. Blunn. 1952. Some factors affecting gestation length and birth weights of beef cattle. J. Anim. Sci. 11:34.

Busch, D. A. and C. A. Kinkel. 1967. Heritability estimates for certain beef traits. J. Anim. Sci. 26:1465 (Abstr.).

Cardellino, R. 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.

Carter, R. C., G. M. Carman, F. S. McClaugherty and P. S. Haydon. 1971a. Genotype-environment interaction in sheep. I. Ewe productivity. J. Anim. Sci. 33:556.

Carter, R. C., G. M. Carman, F. S. McClaugherty and P. S. Haydon. 1971b. Genotype-environment interaction in sheep. II. Lamb performance traits. J. Anim. Sci. 33:732.

Cooper, C. R., T. M. Sutherland, P. S. Pattengale 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.).

Crocket, J. R. and M. Koger. 1975. Exotics for crossbreeding in South Florida. J. Anim. Sci. 40:173 (Abstr.).

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

Cundiff, L. V. 1970. Experimental results on crossbreeding cattle for beef production, J. Anim. Sci. 38:866.

Cundiff, L. V., K. E. Gregory and R. M. Koch. 1974. Effects of heterosis on reproduction in Hereford, Angus and Shorthorn cattle. J. Anim. Sci. 38:711.

Cundiff, L. V., K. E. Gregory and C. R. Long. 1975. Genetic variation among and within herds of Angus and Hereford cattle. J. Anim. Sci. 41:1270.

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

Dhaliwal, J. S., C. F. Parker, D. S. Bell and A. L. Moxon. 1963. A genotype-environment interaction; influence of live-weight of ewe and level of nutrition during late pregnancy on litter size in Columbia sheep. Univ. Udaipur Res. Stud., 1:71-83. (AB.A.A., 34, No. 1304).

Dickerson, G. E. 1962. Implications of genetic-environmental interaction in animal breeding. Anim. Prod. 4:47.

Dunlop, A. A. 1962. Interactions between heredity and environment in the Australian Merino. I. Strain x location interactions in wool traits. Aust. J. Agr. Res. 13:503.

Edwards, J., D. Jobst, J. Hodges, M. Leyburn, L. K. O'Conner, A. MacDonald, G. F. Smith and P. Wood. 1966. The Charolais report. The results of field trials in England and Wales to compare Charolais bulls with bulls of British beef breeds when crossed with dairy cows. Anim. Breed. Abstr. 35: No. 94.

Ellis, G. F., Jr., T. C. Cartwright and W. E. Kruse. 1965. Heterosis for birth weight in Brahman-Hereford crosses. J. Anim. Sci. 24:93.

Falconer, D. S. 1952. The problem of environment and selection. Amer. Nat., 86:293.

Falconer, D. S. and M. Latyxzewski. 1952. The environment in relation to selection for size in mice. J. Genetics, 51:67.

Falconer, D. S. 1960. Selection of mice for growth on high and low planes of nutrition. Genetical Res. 1:91.

Foote, W. D., W. J. Tyler and L. E. Casida. 1959. Effect of some genetic and maternal environmental variations on birth weight and gestation length in Holstein cattle. J. Dairy Sci. 42:305.

Foote, W. D., E. R. Hauser and L. E. Casida. 1960. Effect of uterine horn pregnant, parity of dam, and sex of calf on birth weight and gestation length in Angus and Shorthorn cows. J. Anim. Sci. 19:470.

Fowler, S. H. and M. E. Ensminger. 1960. Interactions between genotype and plane of nutrition in selection for rate of gain in swine. J. Anim. Sci. 19:434.

Freeman, A. E. 1969. Estimates of genotype by environment interaction and effects of contemporaneity upon growth and production from cattle twins. J. Dairy Sci. 52:926 (Abstr.).

Friedrich, R. L., D. D. Kress, D. Vaniman and P. J. Burfening. 1975. Creep feeding and subsequent maternal ability of Simmental cross calves. Proc. West. Sec. Am. Soc. Anim. Sci. 26:14.

Gaines, J. A., W. H. McClure and R. C. Carter. 1966. Purebred vs. crossbred cows of three beef breeds. J. Anim. Sci. 25:870 (Abstr.).

Gowe, R. S. and W. J. Wakely. 1954. Environment and poultry breeding problems. I. The influences of several environments on the egg production and viability of different genotypes. Poultry Sci. 33:691.

Gowe, R. S. 1956. Environment and poultry breeding problems. II. A comparison of egg production of seven S. C. White Leghorn strains housed in laying batteries and floor pens. Poultry Sci. 35:430.

Gregory, Keith E., C. T. Blunn and M. L. Baker. 1950. A study of some of the factors influencing the birth and weaning weights of beef calves. J. Anim. Sci. 9:338.

Gregory, K. E., L. A. Swiger, R. M. Koch, L. J. Sumption, W. E. Rowden and J. E. Insalls. 1965. Heterosis in preweaning traits of beef cattle. J. Anim. Sci. 24:21.

Gregory, K. E., L. A. Swiger, R. M. Koch, L. J. Sumption, J. E. Ingalls, W. W. Rowden, and J. A. Rothlisburger. 1966a. Heterosis effects on growth rate of beef heifers. J. Anim. Sci. 25:290.

Gregory, K. E., L. A. Swiger, R. M. Koch, L. J. Sumption, J. E. Ingalls, W. W. Rowden and J. A. Rothlisburger. 1966b. Heterosis effects on growth rate and feed efficiency of beef steers. J. Anim. Sci. 25:299.

Haldane, J. B. S. 1946. The interaction of nature and nuture. Annuals of Eugenics. 13:197.

Hammond, J. 1947. Animal breeding in relation to nutrition and environmental conditions. Biol. Rev. 22:195.

Harvey, W. R. 1975. Least squares analysis of data with unequal subclass numbers. U.S.D.A. Agr. Rep. Service. ARS H-4.

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

Henderson, C. R. 1953. Estimation of variance and covariance components. Biometrics 9:226-252.

Hill, J. F. and A. W. Nordskog. 1956. Efficiency of performance testing in poultry. Poultry Sci. 35:256.

Hull, P. and R. S. Gowe. 1962. The importance of interactions detected between genotype and environmental factors for characters of economic significance in poultry. Genetics 47:143.

Humes, P. E., R. Bogart, K. E. Rowe and R. E. Schilling. 1973. Heterosis among inbred lines of Hereford cattle for preweaning and weaning traits. J. Anim. Sci. 36:466.

Humes, P. E. Saidi bin Moin and Ismail bin Idris. 1975. Birth and preweaning traits of exotic cross calves. J. Anim. Sci. 41:250 (Abstr.).

Icaza, E. A., A. C. Boston and P. E. Humes. 1974. Age of dam effects in straightbred beef cows. J. Anim. Sci. 39:145 (Abstr.).

Kennedy, B. W. and C. R. Henderson. 1975a. Components of variance of growth traits among Hereford and Aberdeen Angus calves. Can . J. Anim. Sci. 55:493.

Kennedy, B. W. and C. R. Henderson. 1975b. Genetic, environmental and phenotypic correlations between growth traits of Hereford and Aberdeen Angus calves. Can. J. Anim. Sci. 55:503.

King, J. W. B. and G. B. Young. 1955. A study of three breeds of sheep wintered in four environments. J. Agr. Sci. 45:331.

King, J. W. B., J. H. Watson and G. B. Young. 1959. Genotype-environment interactions in the wintering of lambs. J. Agr. Sci. 53:156.

Knapp, Bradford, Jr. and R. W. Phillips. 1942. Differences in performance between sexes in offspring of beef bulls. J. Anim. Sci. 1:346 (Abstr.).

Koch, R. M., K. F. Gregory, J. E. Ingalls and R. L. Arthaud. 1959. Evaluating the infleunce of sex on birth weight and preweaning gain in beef cattle. J. Anim. Sci. 18:738.

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

Koonce, K. L. and E. U Dillard. 1967. Some enfironmental effects on birth weight and gestation length in Hereford cattle. J. Anim. Sci 26:205 (Abstr.).

Kress, D. D., E. R. Hauser and A. B. Chapman. 1971. Genetic-environmental interactions in identical and fraternal twin beef cattle. I. Growth from 7 to 24 months of age. J. Anim. Sci. 33:1177.

Kress, D. D. and P. J. Burfening. 1972. Weaning weight related to subsequent most probable production ability in Hereford cows. J. Anim. Sci. 35:372.

Kress, D. D. and R. P. Webb. 1972. Sex x sire interactions in beef cattle. Proc. West. Sec. Am. Soc. Anim. Sci. Vol. 23.

Kress D. D., P. J. Burfening, D. C. Anderson and R. L. Blackwell. 1973. Early growth of straightline and crossline calves. J. Anim. Sci. 37:236 (Abstr.).

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

Laster, D. B. and K. E. Gregory. 1973. Factors affecting peri- and early postnatal calf mortaility. J. Anim. Sci. 36:1092.

Laster, D. B., H. A. Glimp, L. V. Cundiff and K. E. Gregory. 1973. Factors affecting dystocia and the effects of dystocia on subsequent reproduction in beef cattle. J. Anim. Sci. 36:695.

Laster, D B. 1974. Factors affecting pelvic size and dystocia in beef cattle. J. Anim. Sci. 38:496.

Legates, J. E., F. J. Verlinden and J. F. Kendrick. 1956. Sire by herd interaction in production traits in dairy cattle. J. Dairy Sci. 39:1055.

Legates, J. E. 1962. Heritability of fat yields in herds with different production levels. J. Dairy Sci. 45:990.

Linton, A. C., J. S. Brinks, H. H. Stonaker, T. M. Sutherland and L. C. Faulkner. 1968. Factors affecting weaning weights of cattle. Proc. West. Sec. Amer. Soc. Anim. Sci. 19:319.

Long, C. R. and K. E. Gregory. 1974. Heterosis and breed effects in preweaning traits of Angus, Hereford and reciprocal cross calves. J. Anim. Sci. 39:11.

Lowry, D. C., I. M. Lerner and L. W. Taylor. 1956. Intraflock genetic merit under floor and cage management. Poultry Sci. 35:1034.

Lush, J. L. 1945. Animal Breeding Plans. Iowa State College Press. Ames, Iowa.

Lytton, V. H. and J. E. Legates. L966. Sire by region interaction for production traits in dairy cattle. J. Dairy Sci. 49:874.

Mao, I. L. and E. B. Burnside. 1969. Sire by herd environment interaction for milk production. J. Dairy Sci. 52:1055.

Marlowe, Thomas 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. Anim. Sci. 17:706.

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

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

Meiske, J. C. and R. D. Goodrich. 1975. Comparison of Chianina, Marchigiana and Hereford-sired calves. J. Anim. Sci. 41:272 (Abstr.).

Melton A. A., J. K. Riggs, L. A. Nelson and T. C. Cartwright. 1967. Milk production, composition and calf gains of Angus, Charolais, and Hereford cows. J. Anim. Sci. 26:804.

Morley, F. H. W. 1956. Selection for economic characters in Australian Merino sheep. VII. Interactions between genotype and plane of nutrition. Aust. J. Agr. Res. 7:140.

McBride, G. 1958. The environment and animal breeding problems. Anim. Breed. Abstr. 26:349.

McDaniel, B. T. and E. L. Corley. 1967. Relationships between sire evaluations at different herdmate levels. J. Dairy Sci. 50:735.

Nelms, G. E. and Ralph Bogart. 1956. The effect of birth weight, age of dam and time of birth on suckling gains of beef calves. J. Anim. Sci. 15:662.

Nelsen, T. C. 1976. Time trends, sex and age of dam correction factors, and genetic parameters for production traits in Angus and Hereford cattle. Masters Thesis. Montana State University Bozeman, Montana.

Nelson, A. B., W. Archer, Jr., A. E. Darlow and W. D. Campbell. 1952. Creep feeding calves which are to be sold at weaning. Feeding and breeding tests. Okla. St. Univ. and U.S.D.A. April, M.P. No. 27.

Nelson, A. B., W. D. Campbell and G. Bratcher. 1954. Creep-feeding beef calves. Okla. St. Univ. Feeders Day Reports.

Nelson, A. B., W. D. Campbell, G. Bratcher and R. O. Humphrey. 1955. Creep-feeding beef calves. Feeding and Breeding Tests. Okla St. Univ. and U.S.D.A. April, M.P. No. 43.

Nunn, T. S. 1974. Sire by region interaction for production traits in beef cattle. Masters Thesis. Montana State University, Bozeman, Montana.

Osman, A. H. and G. E. Bradford. 1965. Effects of environment on phenotype and genetic variation in sheep. J. Anim. Sci. 24:766.

Osman, A. H. and G. E. Bradford. 1967. Genotype-environment interaction and compensatory growth in sheep. J. Anim. Sci. 26:1239.

Pahnish, O. F., E. B. Stanley, R. Bogart and C. B. Roubicek. 1961. Influence of sex and sire on weaning weight of Southwestern range calves. J. Anim. Sci. 20:454.

Pahnish, O. F., R. L. Roberson, R. L. Raylor, J. S. Brinks, R. T. Clark and C. B. Roubicek. 1964. Genetic analyses of economic traits measured in range-raised Herefords at preweaning and weaning ages. J. Anim. Sci. 23:562.

Pani, S. N. and J. F. Lasley. 1972. Genotype x environment interactions in animals. Mo. Agr. Exp. Sta. Res. Bull. 992.

Petty, Robert R., Jr. and T. C. Cartwright. 1966. A summary of genetic and environmental statistics for growth and conformation traits of young beef cattle. Dept. Tech. Rept No. 5. Texas Agr. Exp. Sta.

Preston, T. R. and M. B. Willis. 1974. Intensive Beef Production. Persamon Press, New York.

Ramsay, J. M. and A. E. Freeman. 1965. A genotype by environment interaction for two growth traits. J. Dairy Sci., 48:804.

Rankin, B. J. and L. A. Holland. 1974. Weaning data on Hereford, Brangus and crossbreds. J. Anim. Sci. 38:1321 (Abstr.).

Robertson, Alan. 1959. The sampling variance of the genetic correlation coefficient. Biometrics 15:469.

Robertson, Alan, L. K. O'Connor and J. Edwards. 1960. Progeny testing dairy bulls at different management levels. Anim. Prod. 2:141.

Sagebiel, J. A., G. F. Krause, Bob Sibbit, L. Langford, A. J. Dyer and J. F. Lasley. 1973. Effects of heterosis and maternal influences on gestation length and birth weight in reciprocal crosses among Angus, Charolais and Hereford cattle. J. Anim. Sci. 37:1273.

Sagebiel, J. A., G. F. Krause, Bob Sibbit, L. Langford, A. J. Dyer and J. F. Lasley. 1974. Effects of heterosis and maternal influences on weaning traits in reciprocal crosses among Angus, Charolais and Hereford cattle. J. Anim. Sci. 39:471

Scarth, R. D., R. C. Miller, P. J. Phillips, G. W. Sherritt and J. H. Ziegler. 1968. Effects of creep feeding and sex on the rate and composition of growth of crossbred calves. J. Anim. Sci. 27:596.

Schaeffer, L. R. and J. W. Wilton. 1974a. Age of dam, sex and environmental interaction affecting preweaning average daily gain of beef cattle. Can. J. Anim. Sci. 54:183.

Schaeffer, L. R. and J. W. Wilton. 1974b. Comparison of the effectiveness of multiplicative and additive adjustment factors in preweaning average daily gain of beef cattle. Can. J. Anim. Sci. 54:519.

Schaeffer, L. R., and I. L. Mao. 1975. Problems in estimating genetic parameters in dairy cattle. I. Disconnectedness among subclasses. J. Dairy Sci. 58:773. (Abstr.).

Schaeffer, L. R. and J. W. Wilton. 1975. Predicting beef sire genetic values for growth traits from progeny records. J. Anim. Sci. 41:1592.

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

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

Smith, G. M., D. B. Laster and Keith E. Gregory. 1976. Characterization of biological types of cattle. I. Dystocia and preweaning growth. J. Anim. Sci. 43:27.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. (6th Ed). Iowa State University Press. Ames.

Stanforth, T. A. and R. R. Frahm. 1974. Performance to weaning of two breed cross calves. J. Anim. Sci. 39:151 (Abstr.).

Tanner, J. E., R. R. Frahm and J. V. Whiteman. 1969. Sire-sex interactions and sex differences in cattle. J. Anim. Sci. 29:112. (Abstr.).

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.

Taylor, J. C., R. C. Carter, C. M. Kincaid, B. M. Priode and J. A. Gaines. 1960. Estimates of genetic and phenotypic parameters in beef cattle. IV. Repeatability of cow performance. J. Anim. Sci. 19:700.

Thrift, F. A., D. D. Kratzer and J. D. Kemp. 1970. Effect of sire, sex and sire x sex interactions on beef cattle performance and carcass traits. J. Anim. Sci. 30:182.

Turner, J. W. and R. P. MacDonald. 1969. Preweaning performance of crossbred beef calves. J. Anim. Sci. J. Anim. Sci. 28:131 (Abstr.).

Urich, J. J., J. S. Brinks, O. F. Pahnish, B. W. Knapp and T. W. Riley. 1968. Heterosis in preweaning traits among lines of Hereford cattle. J. Anim. Sci. 27:323.

Van Vleck, L. D., L. H. Wadell and C. R. Henderson. 1961. Components of variance associated with milk and fat records of artificially sired Holstein daughters. J. Anim. Sci. 20:812.

Van Vleck, L. D. 1963. Genotype and environment in sire evaluation. J. Dairy Sci. 46:983.

Wiggans, G. R. and L. D. Van Vleck. 1970. Sire effects in different housing systems. J. Dairy Sci. 53:545.

Wilson, L. L., J. H. Ziegler, J. L. Watkins, C. E. Thompson and H. R. Purdy. 1969. Influence of sex and sire on growth and carcass traits of beef cattle. J. Anim. Sci. 38:607.

Wilson, L. L., W. H. Rishel and W. R. Harvey. 1972. Influence of herd, sire and herd by sire on live and carcass characters of beef cattle. J. Anim. Sci. 35:502.

Wiltbank, J. N., K. E. Gregory, J. A. Rothlisberger, J. E. Insalls and C. W. Kasson. 1967. Fertility in beef cows bred to produce straightbred or cross bred calves. J. Anim. Sci. 26:1005.

Woodward, R. R. and R. T. Clark. 1950. The repeatability of performance of several Hereford sires as measured by progeny records. J. Anim. Sci. 9:588.

Yamada, Yukio. 1962. Genotype by environment interaction and genetic correlation of the same trait under different environments. Jap. Jour. Genet. 37:498.

APPENDIX

APPENDIX TABLE 1. NUMBER OF PROGENY PER SIRE (n_1) AND THE NUMBER OF MANAGEMENT UNITS IN WHICH EACH SIRE (n_2) WAS USED FOR EACH DATA SET

	Model 1							
	NCF 1/2		CF 1/2		NCF 3/4		CF 3/4	
Sire code	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2
1*	100	19	301	23	131	35	228	37
2*	161	30	209	20				
3*	76	8	17	4	148	31	53	8
4*	61	19	100	13	147	32	163	21
5*			20	5				
6*	42	6			52	9		
7*	57	10	21	7	50	7	32	1
8*	35	12	24	4				
9*	29	6	40	7	211	37	124	15
10*	292	45	89	14	571	115	376	51
11*	347	57	71	19	726	120	209	42
12*	165	24	137	17	781	136	236	46
13*	39	9	11	3			31	5
14*			18	6	288	44	31	9
15*			14	4			37	2
16*			8	2			54	8
17*	20	5			94	25		
18*	206	26	47	8	658	110	213	32
19*	511	18	89	13	527	86	345	34
20*	57	12			144	34	49	7
21*	48	12	25	5	203	42	48	12
22	32	7						
24*	49	7			73	15		
25*	217	34	37	3	147	28	75	16
26*	43	11			139	28	45	7
27*	165	25	26	4	390	77	165	27
28*	44	15	7	3	111	25	50	9
29*					58	9		
30*					54	14		
31*					5	2		
32*	31	8					23	7
33*	63	10	12	4	194	37	74	11
34*					75	12	28	8
35*	86	7			303	37	62	14
36*					79	11		
37*	21	3						

APPENDIX TABLE 1 (CONTINUED)

	Model 1							
	NCF 1/2		CF 1/2		NCF 3/4		CF 3/4	
Sire code	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2
38*	45	6	14	2				
39*	83	7	17	4	197	30	64	7
40*	74	14	28	6	230	50	54	11
41*	40	4			167	23	139	10
42*	53	11			64	14	41	4
43*			11	3				
44*							108	6
45*	40	3					29	5
46*							27	4
47*	41	10	12	3	98	21	80	12
48*	158	35	111	11	413	69	120	21
49*	59	1						
50*			23	3	148	11		
51*			77	7			80	11
52			13	2				
53							27	4
54*			18	3	243	33	163	14
55*	97	9	56	3	51	12		
56*	107	11	28	2	47	12	9	3
57	38	5						
58	35	4						
62*	32	8						
63			13	1				
65	38	6						
66*					54	12		
67*					48	9		
68			26	4				
70*	73	14	8	2				
72*	52	6			56	15		
74			9	1				
75			16	2			80	7
76							26	4
78			16	2				
79			20	4				
80*					55	12		
81							43	4
82			13	1				
84							42	2
86							22	2
87			17	1				

APPENDIX TABLE 1. (CONTINUED)

	Model 1							
	NCF 1/2		CF 1/2		NCF 3/4		CF 3/4	
Sire code	n_1	n_2	n_1	n_2	n_1	n_2	n_1	n_2
88					57	6		
89							30	2
91*							24	6
93			16	2				
94					73	5		
96							42	6
98							33	4
99					48	2		

	Model II			
	NCF 1/2		NCF 3/4	
	n_1	n_2	n_1	n_2
1*	13	1	54	14
2*	23	5		
3*	9	2	69	8
4*			70	12
6*	14	1	20	2
7*	20	2	27	8
9*	10	2	96	12
10*	14	3	169	25
11*	60	6	276	28
12*	55	4	326	31
14*			56	10
16*	16	1		
17*			32	5
18*	38	4	216	21
19*	18	3	281	27
20*	11	2	43	7
21*	38	4	72	14
23*	7	1		
24*	27	7		
25*	18	3	54	6
26*	50	3	40	9
27*	28	7	142	12
30*	13	1	24	6
32*			49	7
33*	31	1	63	13
34*			39	4

APPENDIX TABLE 1. (CONTINUED)

	Model II			
	NCF 1/2		NCF 3/4	
Sire code	n_1	n_2	n_1	n_2
35*	30	1	140	9
36*			21	3
38*	30	2		
39*	32	1	75	4
40*	17	1	76	8
41*			36	4
42*	17	1		
44*	7	1		
45*	8	1		
47*			45	6
48*	21	4	142	19
49*	59	1		
54*	12	1	123	9
55*			19	2
56*	31	3		
58	28	1		
59	10	1		
60*	13	1		
61*	14	2		
62*	10	1		
64	7	1		
65	17	1		
66*			49	6
69*	22	1		
70*	102	2	115	6
71*	11	2		
72*	19	1		
73*	29	2		
75			18	1
77			20	2
83			18	3
85	9	2		

APPENDIX TABLE 1. (CONTINUED)

Sire code	Model II			
	NCF 1/2		NCF 3/4	
	n_1	n_2	n_1	n_2
88			44	2
90			21	3
92			19	1
95			23	2
97			40	4
99			29	1
100			28	1
101			34	1
102			25	2

* Denotes designated reference sires.

APPENDIX TABLE 2. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg), PREWEANING AVERAGE DAILY GAIN (kg/day) AND WEANING WEIGHT (kg) (MODEL I)

Data set	n	Birth weight	Average daily gain	Weaning weight
NCF 1/2	4106	36.9±.9	.84±.04	208.6± 8.9
CF 1/2	1885	36.6±.9	.81±.06	202.3±11.8
NCF 3/4	8612	38.5±.4	.95±.02	232.7± 3.9
CF 3/4	4033	38.7±.5	.96±.02	235.5± 5.1

APPENDIX TABLE 3. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg) FOR THE BULL AND HEIFER PROGENY (MODEL I)

	Sex	
Data set	Bull	heifer
NCF 1/2	38.5± .9 (867)	35.3± .9 (3239)
CF 1/2	37.9±1.0 (280)	35.3±1.0 (1605)
NCF 3/4	40.1± .4 (2541)	36.8± .4 (6071)
CF 3/4	40.1± .5 (1359)	37.3± .5 (2674)

APPENDIX TABLE 4. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg) FOR EACH AGE OF DAM (MODEL I)

Data set	Age of dam (years) 2	3	4	5 or older
NCF 1/2	36.4±1.0 (300)	36.2± .9 (686)	37.5± .9 (716)	37.6± .9 (2404)
CF 1/2	34.6±1.1 (83)	37.5±1.0 (402)	37.0±1.0 (289)	37.3±1.0 (1111)
NCF 3/4	36.6± .4 (4671)	38.3± .4 (2449)	39.3± .4 (1202)	39.8± .5 (290)
CF 3/4	36.3± .5 (2124)	38.4± .4 (1288)	40.0± .5 (495)	40.1± .6 (126)

APPENDIX TABLE 5. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg) FOR EACH SEX IN EACH AGE OF DAM (MODEL I)

Data set		Age of dam (years) 2		3		4		5 or older	
NCF 1/2	Males	37.8±1.2	(44)	37.7±1.0	(131)	39.2±1.0	(175)	39.4± .9	(517)
NCF 1/2	Females	34.9± .9	(256)	34.8± .9	(555)	35.8± .9	(541)	35.9± .9	(1887)
CF 1/2	Males	37.4±1.6	(11)	39.4±1.2	(30)	38.2±1.1	(51)	38.3±1.0	(188)
CF 1/2	Females	33.7±1.0	(72)	35.5±1.0	(372)	35.8±1.0	(238)	36.4±1.0	(932)
NCF 3/4	Males	38.1± .4	(1324)	40.0± .4	(764)	40.8± .5	(373)	41.6± .7	(80)
NCF 3/4	Females	35.0± .4	(3347)	36.6± .4	(1685)	37.8± .4	(829)	38.0± .5	(210)
CF 3/4	Males	37.4± .6	(689)	39.8± .6	(455)	41.5± .6	(169)	41.6± .8	(46)
CF 3/4	Females	35.3± .5	(1435)	36.9± .6	(833)	38.5± .5	(326)	38.5± .7	(80)

APPENDIX TABLE 6. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg) (BRWT), PREWEANING AVERAGE DAILY GAIN (kg/day) (ADG) AND WEANING WEIGHT (kg) (WNWT) FOR EACH SIRE (MODEL II)

NCF 1/2 Sire code	n	BRWT		ADG		WNWT	
		Mean	SE	Mean	SE	Mean	SE
1	100	36.4	1.1	.87	.05	214.9	9.8
2	161	37.1	1.0	.83	.04	206.5	9.4
3	76	36.3	1.0	.82	.04	205.6	9.6
4	61	35.7	1.3	.87	.05	213.8	10.9
6	42	37.9	1.1	.89	.65	221.2	10.1
7	57	37.6	1.3	.85	.05	211.9	10.8
8	35	35.5	1.3	.81	.05	202.6	11.0
9	29	35.7	1.3	.82	.05	203.6	10.7
10	292	36.4	.9	.85	.04	211.0	9.1
11	347	35.5	.9	.82	.04	203.5	9.1
12	165	37.3	.9	.83	.04	207.5	9.2
13	39	38.2	1.8	.82	.06	204.0	13.4
17	20	39.9	2.1	.97	.07	239.7	15.2
18	206	38.5	.9	.87	.04	216.6	9.2
19	511	37.7	1.1	.87	.05	215.9	10.0
20	57	36.5	1.1	.88	.05	216.5	9.7
21	48	38.3	1.1	.86	.06	214.8	10.1
22	32	37.3	1.3	.86	.05	213.0	10.9
24	49	35.9	1.2	.86	.05	193.3	10.5
25	217	26.5	.9	.77	.04	203.4	9.3
26	43	39.2	2.1	.81	.07	216.7	15.3
27	165	35.6	.9	.86	.04	210.2	7.2
28	44	36.1	1.2	.78	.05	197.6	10.3
32	31	37.1	2.3	.73	.08	185.8	16.5
33	63	38.4	1.1	.83	.05	207.7	9.8
35	86	37.7	1.1	.83	.05	207.1	9.8
37	21	37.7	1.5	.79	.05	200.3	11.9
38	45	35.6	1.1	.81	.05	201.8	9.9
39	83	33.6	1.1	.77	.05	190.8	9.8
40	74	38.6	1.1	.80	.05	202.9	9.8
41	40	35.2	1.3	.81	.05	201.1	11.0
42	53	35.2	1.3	.78	.05	194.3	10.7
45	40	36.2	1.1	.91	.05	223.6	10.0
47	41	39.0	1.1	.82	.05	215.4	9.8
48	158	35.0	1.0	.84	.04	208.5	9.5

APPENDIX TABLE 6. (CONTINUED)

NCF 1/2 Sire Code	n	BRWT Mean	BRWT SE	ADG Mean	ADG SE	WNWT Mean	WNWT SE
49	59	36.7	1.1	.77	.05	194.2	10.1
55	97	35.2	1.1	.83	.05	205.1	9.9
56	107	37.8	1.0	.83	.05	208.0	9.7
57	38	39.2	1.5	.96	.06	236.1	12.0
58	35	37.5	1.4	.83	.05	207.1	11.0
62	32	35.3	1.2	.88	.05	216.3	10.3
65	38	37.2	1.4	.89	.05	219.3	11.3
70	73	35.2	1.1	.78	.05	196.1	9.9
71	44	41.1	1.4	.81	.05	206.5	11.1
72	52	36.3	1.1	.88	.05	216.7	9.9

APPENDIX TABLE 6. (CONTINUED)

NCF 3/4 Sire Code	n	BRWT Mean	BRWT SE	ADG Mean	ADG SE	WNWT Mean	WNWT SE
1	131	38.8	.6	.94	.02	232.8	4.5
3	148	39.4	.6	.96	.02	236.6	4.5
4	147	36.9	.6	.91	.02	224.9	4.5
6	52	39.8	.7	.92	.03	229.1	5.9
7	50	37.7	.9	.88	.03	218.5	5.9
9	211	38.5	.6	.90	.02	224.8	4.5
10	571	38.6	.5	.95	.02	233.8	4.1
11	726	37.7	.5	.90	.02	224.2	4.1
12	781	39.5	.5	.96	.02	236.7	4.1
14	238	38.8	.6	.94	.02	231.7	4.5
17	94	39.7	.7	1.00	.02	245.6	5.0
18	658	38.7	.5	.93	.02	231.1	4.1
19	527	39.6	.5	.95	.02	235.3	4.1
20	144	38.6	.6	.96	.02	237.2	4.5
21	203	40.4	.5	.95	.02	235.8	.45
24	73	37.8	1.1	.95	.03	234.2	6.8
25	146	33.4	.6	.90	.02	223.2	4.5
26	139	37.0	.6	.95	.02	232.5	4.5
27	390	39.1	.5	.96	.02	236.6	4.1
28	111	38.8	.8	.88	.03	221.0	5.0
29	48	38.4	1.0	.93	.03	229.3	5.9
30	54	39.6	.8	.91	.03	226.4	5.4
31	5	35.8	2.1	.92	.06	224.9	11.9
33	194	39.2	.6	.95	.02	235.3	4.5
34	75	40.0	.7	.95	.03	235.6	5.0
35	303	40.5	.5	.95	.02	236.6	4.5
36	79	39.5	.8	.97	.03	239.4	5.4
39	197	35.6	.6	.89	.02	219.1	4.5
40	230	38.1	.5	.94	.02	232.8	4.5
41	167	38.5	.6	.94	.02	233.1	4.5
42	64	37.7	.9	.94	.03	230.7	5.9
47	98	38.5	.7	.89	.03	222.8	5.0
48	413	38.5	.5	.95	.02	233.8	4.1
50	148	38.9	.6	1.00	.02	244.2	4.5
54	243	38.4	.6	.94	.02	232.6	4.5

APPENDIX TABLE 6. (CONTINUED)

NCF 3/4 Sire Code	n	BRWT Mean	BRWT SE	ADG Mean	ADG SE	WNWT Mean	WNWT SE
55	51	38.5	.9	.92	.03	228.8	5.9
56	47	38.6	1.1	.95	.03	234.6	6.8
66	54	37.4	1.2	.92	.03	225.9	7.2
67	48	38.9	1.0	.92	.03	229.1	6.3
70	215	38.1	.6	.95	.02	233.6	4.5
72	56	38.3	.8	.97	.03	236.9	5.4
80	55	37.9	.9	.97	.03	237.3	5.4
88	57	38.2	1.0	.99	.03	242.2	6.3
94	73	38.0	.9	1.03	.03	249.4	5.9
99	48	37.6	1.1	1.04	.03	250.0	6.8

APPENDIX TABLE 6. (CONTINUED)

CF 1/2 Sire Code	n	BRWT Mean	BRWT SE	ADG Mean	ADG SE	WNWT Mean	WNWT SE
1	301	37.7	1.2	.77	.06	94.8	13.1
2	209	35.2	1.3	.75	.06	190.3	13.1
3	17	37.8	1.4	.83	.07	207.8	14.1
4	100	36.1	1.0	.84	.06	208.6	12.2
5	20	38.7	1.4	.83	.07	210.1	14.1
7	21	38.1	1.4	.75	.07	193.2	13.7
8	24	37.4	1.4	.74	.07	190.6	13.6
9	40	37.8	1.2	.78	.06	197.2	13.1
10	89	34.2	1.2	.86	.06	210.5	12.7
11	71	33.4	1.5	.78	.07	192.4	15.0
12	137	37.2	1.2	.86	.06	213.6	13.1
13	11	36.1	1.4	.78	.07	196.3	14.1
14	18	36.6	1.5	.83	.07	206.5	14.5
15	14	38.4	1.5	.79	.07	201.8	15.0
16	8	38.8	2.3	.83	.09	207.9	19.7
18	47	37.6	1.2	.83	.06	206.6	13.1
19	89	36.8	1.1	.76	.06	192.8	12.7
21	25	38.2	1.2	.86	.06	214.3	13.1
25	37	34.7	1.4	.75	.07	189.7	14.1
27	26	34.6	1.3	.81	.06	200.0	13.6
28	7	36.6	1.9	.78	.08	197.7	16.8
33	12	36.9	1.4	.86	.07	211.5	14.5
38	14	36.8	1.5	.76	.07	193.1	14.5
39	17	37.3	1.4	.79	.07	199.7	14.1
40	28	37.9	1.4	.86	.07	214.6	14.1
43	11	37.0	1.5	.82	.07	205.8	14.5
47	12	39.6	1.7	.85	.08	214.9	15.9
48	111	36.0	1.1	.87	.06	213.6	12.2
50	23	39.1	2.1	.79	.09	200.9	18.1
51	77	36.9	1.2	.84	.06	209.1	12.7
52	31	36.1	1.5	.94	.07	229.7	14.5
54	18	38.1	2.1	.79	.09	199.4	18.1
55	56	33.9	1.2	.86	.06	210.8	13.1
56	28	34.4	1.6	.80	.07	198.8	15.4
63	13	32.7	1.8	.82	.08	200.2	16.8

APPENDIX TABLE 6. (CONTINUED)

CF 1/2 Sire code	n	BRWT Mean	BRWT Se	ADG Mean	ADG Se	WNWT Mean	WNWT SE
68	26	36.7	1.3	.80	.07	201.8	13.6
71	8	40.5	1.9	.85	.08	216.0	17.2
74	9	28.5	2.4	.70	.10	172.5	20.0
75	16	37.8	1.5	.80	.07	202.3	14.5
78	16	36.3	1.6	.83	.07	205.8	15.4
79	20	37.9	1.5	.84	.07	211.6	14.5
82	13	34.0	3.0	.60	.12	157.0	24.0
87	17	38.4	1.8	.83	.08	207.6	16.3
93	16	35.5	1.3	.83	.07	205.2	13.6

APPENDIX TABLE 6. (CONTINUED)

CF 3/4 Sire code	n	BRWT Mean	BRWT SE	ADG Mean	ADG SE	WNWT Mean	WNWT SE
1	228	39.3	.6	.97	.03	238.4	5.4
3	53	40.6	1.2	.94	.04	235.5	7.7
4	163	37.2	.7	.94	.03	230.3	5.4
7	32	40.3	2.3	1.06	.06	257.8	12.7
9	124	37.8	.7	.99	.03	235.0	5.9
10	376	38.2	.6	.95	.03	234.3	5.4
11	209	37.1	.6	.92	.03	227.9	5.4
12	236	39.9	.6	.97	.03	240.0	5.4
13	31	41.5	1.1	1.00	.03	248.7	7.2
14	31	38.8	1.2	.94	.04	232.2	7.7
15	37	38.1	1.2	.99	.04	242.4	7.7
16	54	39.4	1.3	.94	.04	233.3	8.1
18	213	37.4	.7	.99	.03	240.6	5.9
19	345	40.7	.6	.97	.03	240.4	5.4
20	49	39.0	1.0	.93	.03	230.8	6.8
21	48	40.5	.9	.98	.03	240.9	6.3
25	75	39.7	.8	.93	.03	230.6	5.9
26	45	37.7	1.5	.97	.04	237.4	9.0
27	165	37.0	.7	.97	.03	248.7	5.4
28	50	37.9	1.3	.94	.04	232.4	8.1
32	23	38.1	1.5	.95	.04	233.3	9.1
33	74	40.4	.8	1.00	.03	245.7	6.3
34	28	39.9	1.2	.95	.04	235.1	7.7
35	62	40.4	.9	.99	.03	245.4	6.3
39	64	34.9	.9	.92	.03	224.8	6.3
40	54	38.3	.8	.98	.03	241.0	6.3
41	139	36.1	.8	.96	.03	233.4	5.9
42	41	35.7	1.0	.95	.03	230.8	7.2
44	108	38.2	.8	.96	.03	235.8	5.9
45	29	39.2	1.0	.97	.03	239.2	6.8
46	27	39.1	1.1	.09	.03	241.0	7.2
47	80	39.2	.9	.93	.03	231.4	6.3
48	120	39.0	.8	1.00	.03	245.0	5.9
51	80	40.3	.8	.95	.03	235.8	6.3
53	27	39.6	1.4	.87	.04	218.0	8.5

APPENDIX TABLE 6. (CONTINUED)

CF 3/4

Sire code	n	BRWT Mean	BRWT SE	ADG Mean	ADG SE	WNWT Mean	WNWT SE
54	162	39.0	.7	.98	.03	242.1	5.4
56	9	36.3	1.8	.97	.05	237.2	10.7
75	80	39.0	.8	.92	.03	228.8	5.9
76	26	36.6	1.1	.88	.04	218.3	7.2
81	43	39.0	1.5	.88	.04	220.9	9.1
84	42	39.3	1.5	.99	.04	243.6	9.1
86	22	38.2	2.2	.97	.06	239.2	12.7
89	30	38.0	2.2	.90	.06	223.8	12.7
90	24	38.2	1.3	.91	.04	224.3	8.1
96	42	37.9	1.1	.91	.04	225.2	7.2
98	33	37.6	1.0	.96	.03	237.1	6.8

APPENDIX TABLE 7. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg) (RWT), PREWEANING AVERAGE DAILY GAIN (kg/day) (ADG) AND WEANING WEIGHT (kg) (WNWT) FOR EACH SEX WITHIN EACH SIRE (MODEL I)

NCF 1/2			BRWT				ADG				WNWT			
			Males		Females		Males		Females		Males		Females	
Sire code	n_1	n_2	μ	SE	μ	SE	μ	SE	μ	SE	μ	SE	μ	SE
1	14	86	37.3	1.5	35.5	1.0	.94	.05	.80	.04	230.0	11.3	199.9	9.5
2	32	129	38.7	1.2	35.6	1.0	.85	.05	.80	.04	213.8	10.0	199.2	9.5
3	23	53	37.2	1.3	35.5	1.1	.84	.05	.81	.04	208.8	10.9	202.3	10.0
4	8	53	37.7	2.1	33.8	1.1	.97	.07	.77	.04	236.0	14.5	191.6	9.5
6	11	31	40.5	1.6	35.2	1.2	.97	.05	.82	.04	239.8	11.9	202.6	10.0
7	5	52	39.4	2.0	35.7	1.1	.92	.07	.77	.04	229.3	14.5	194.6	10.0
8	7	28	34.6	2.0	36.4	1.4	.87	.07	.86	.05	213.2	14.1	191.9	10.9
9	7	22	37.7	1.8	33.6	1.3	.84	.06	.80	.05	210.1	13.6	197.1	10.4
10	95	197	37.8	1.0	35.0	1.0	.91	.04	.79	.04	223.9	9.5	198.0	9.0
11	63	284	36.1	1.0	34.9	1.0	.88	.04	.76	.04	216.0	9.5	191.1	9.0
12	52	113	38.6	1.1	36.0	1.0	.85	.04	.81	.05	213.5	9.5	201.5	9.5
13	2	37	40.9	3.2	35.5	1.2	.79	.10	.82	.04	20.34	21.3	204.6	10.4
17	2	18	43.6	3.9	36.2	1.4	1.07	.12	.87	.05	263.9	25.4	215.5	10.9
18	46	160	40.3	1.1	35.5	1.0	.93	.04	.81	.04	230.5	10.0	202.6	9.0
19	9	502	39.9	1.7	35.6	1.0	.91	.05	.82	.04	227.6	12.7	204.3	9.4
20	17	40	38.4	1.4	34.6	1.1	.92	.05	.83	.04	227.3	10.9	205.7	10.0
21	14	34	41.2	1.5	35.3	1.2	.90	.05	.82	.05	226.4	11.9	203.1	10.4
22	5	27	40.6	2.0	34.1	1.3	.93	.07	.78	.05	231.1	14.1	194.9	10.9
24	11	38	37.9	1.7	34.0	1.2	.81	.05	.73	.05	203.6	12.2	182.9	10.4
25	74	143	37.7	1.1	35.2	1.0	.86	.04	.76	.04	214.9	80.0	192.0	9.0
26	1	42	43.8	3.9	34.6	1.2	.91	.12	.81	.05	232.2	25.4	200.2	10.0
27	52	113	36.9	1.1	34.2	1.0	.92	.04	.78	.04	226.8	9.5	143.7	9.4
28	12	32	37.7	1.6	34.4	1.2	.82	.06	.75	.05	206.7	12.2	188.5	10.4
32	1	30	39.2	4.4	35.0	1.3	.69	.14	.76	.05	181.5	28.9	190.2	10.4
33	25	38	38.4	1.3	38.3	1.2	.85	.05	.80	.05	213.0	10.4	202.4	10.0
35	18	68	37.9	1.4	37.4	1.1	.85	.05	.80	.04	212.2	11.3	201.9	10.0
38	16	29	36.4	1.4	34.8	1.2	.84	.05	.78	.04	207.8	11.3	195.7	10.0
39	13	65	33.9	1.4	33.3	1.1	.78	.05	.75	.04	193.5	11.3	188.2	9.5
40	17	57	39.8	1.5	37.5	1.1	.82	.05	.78	.04	208.2	11.3	197.7	10.0
42	7	46	37.4	1.9	32.9	1.2	.81	.06	.74	.04	202.9	13.6	185.7	10.0
45	21	19	37.6	1.3	34.8	1.3	1.04	.05	.78	.05	251.8	10.9	195.3	10.9
47	15	26	41.6	1.4	36.3	1.2	.94	.05	.78	.05	243.5	10.9	196.3	10.4
48	18	140	35.3	1.4	34.6	1.0	.89	.05	.79	.04	218.5	10.9	198.4	9.5
49	30	29	38.7	1.3	34.8	1.3	.81	.05	.72	.05	205.1	10.4	183.3	10.4
55	11	86	35.1	1.5	35.2	1.1	.84	.05	.81	.04	208.0	11.9	202.1	10.0
56	21	86	39.4	1.4	36.2	1.1	.87	.05	.79	.04	217.5	10.9	198.5	9.5
57	4	34	41.6	2.5	36.9	1.2	1.17	.08	.75	.05	281.2	17.2	191.1	10.4
58	9	26	38.8	1.7	36.2	1.4	.91	.06	.74	.05	225.1	12.7	189.2	10.9
62	12	20	36.2	1.5	34.5	1.3	.96	.05	.80	.05	233.7	11.9	198.8	10.9
65	5	33	39.8	2.0	34.6	1.3	.98	.07	.79	.05	242.0	14.5	196.6	10.4
70	22	51	34.2	1.4	36.2	1.2	.78	.05	.79	.05	194.8	10.9	192.4	10.0
71	6	38	43.7	2.1	38.4	1.2	.80	.07	.81	.05	207.3	14.5	205.7	10.0
72	29	23	37.7	1.3	34.9	1.4	.93	.05	.83	.05	227.8	10.4	205.5	10.9

APPENDIX TABLE 7. (CONTINUED)

NCF 1/2 Sire code	n_1	n_2	BRWT Males μ	BRWT Males SE	BRWT Females μ	BRWT Females SE	ADG Males μ	ADG Males SE	ADG Females μ	ADG Females SE	WNWT Males μ	WNWT Males SE	WNWT Females μ	WNWT Females SE
1	11	290	40.0	1.8	35.4	1.0	.74	.08	.79	.05	192.6	16.3	196.9	12.2
2	34	175	34.4	2.0	36.1	1.0	.74	.08	.77	.06	186.6	17.7	194.0	12.2
3	11	9	39.5	1.6	38.1	1.6	.87	.97	.79	.07	218.1	15.4	202.1	15.4
7	5	16	40.5	1.9	35.7	1.3	.80	.09	.71	.06	205.5	16.8	180.9	13.6
8	15	9	37.9	1.5	37.0	1.7	.74	.07	.75	.09	190.4	14.1	190.7	15.9
9	18	22	40.9	1.6	34.6	1.4	.84	.07	.71	.07	212.8	15.4	181.5	14.1
10	24	65	35.0	1.4	33.5	1.1	.91	.07	.81	.07	221.4	13.4	199.6	12.7
11	3	68	32.0	2.5	34.9	1.1	.77	.10	.78	.06	190.6	21.3	194.1	12.2
12	8	129	39.4	1.7	35.1	1.0	.90	.07	.82	.06	224.9	15.9	202.3	11.9
14	3	15	38.4	2.3	34.8	1.5	.85	.09	.80	.07	213.2	19.5	199.8	14.5
15	11	3	40.0	1.8	36.8	2.1	.84	.08	.75	.09	211.3	16.3	192.3	18.1
16	1	7	37.1	3.5	40.6	2.5	.99	.13	.66	.10	240.5	28.1	175.2	20.9
18	15	32	39.3	1.5	36.0	1.2	.88	.07	.76	.06	220.3	14.5	192.9	13.1
19	19	70	38.7	1.4	34.9	1.1	.75	.07	.77	.06	192.8	14.1	192.7	12.2
25	26	11	33.6	2.2	35.7	1.5	.74	.09	.77	.07	194.9	18.6	194.6	14.5
39	4	13	39.6	1.9	35.1	1.4	.82	.08	.76	.07	207.6	17.2	191.7	14.1
40	7	21	40.2	1.9	35.6	1.4	.92	.08	.80	.07	228.7	1.68	200.6	13.6
47	2	10	46.4	2.8	32.8	1.5	.90	.11	.81	.07	231.2	22.7	198.5	14.5
48	33	78	36.7	1.2	35.4	1.0	.92	.06	.81	.06	225.5	13.1	201.7	12.2
50	1	22	43.8	3.4	34.6	1.4	.83	.13	.75	.07	214.2	27.2	137.7	14.1
51	20	57	37.9	1.4	35.9	1.1	.87	.06	.80	.06	217.9	13.6	200.3	12.7
52	3	10	36.5	2.2	35.6	1.5	1.16	.09	.73	.07	274.4	18.6	135.0	15.0
54	1	17	39.2	3.4	37.0	1.5	.74	.13	.83	.07	191.5	27.7	207.2	14.5
78	2	14	36.5	2.5	36.0	1.4	.88	.10	.77	.07	216.9	20.9	194.6	14.1
79	3	17	36.6	2.2	39.3	1.3	.93	.09	.76	.06	227.3	19.1	195.8	13.6

APPENDIX TABLE 7. (CONTINUED)

NCF 3/4 Sire code	n_1	n_2	BRWT Males μ	BRWT Males SE	BRWT Females μ	BRWT Females SE	ADG Males μ	ADG Males SE	ADG Females μ	ADG Females SE	WNWT Males μ	WNWT Males SE	WNWT Females μ	WNWT Females SE
1	38	93	40.2	.8	37.3	.6	.99	.03	.90	.02	243.0	5.4	222.8	4.5
3	40	108	41.6	.8	37.3	.6	1.01	.03	.91	.02	248.6	5.4	4.5	
4	39	108	38.0	.8	35.7	.6	.96	.03	.88	.02	234.4	5.4	215.5	4.5
6	21	31	43.1	1.2	36.6	1.0	.96	.03	.89	.03	240.0	7.2	218.2	6.3
7	11	39	38.3	1.4	37.1	.9	.87	.04	.90	.03	216.1	8.1	220.9	5.9
9	61	150	39.8	.7	37.2	.6	.96	.02	.86	.02	236.4	5.0	213.1	4.5
10	193	378	40.1	.5	37.0	.5	1.00	.02	.90	.02	245.3	4.1	222.5	4.1
11	230	496	39.1	.5	36.3	.5	.95	.02	.87	.02	233.5	4.1	214.9	4.1
12	261	520	41.0	.5	37.9	.5	1.01	.02	.91	.02	248.8	4.1	224.1	4.1
14	49	239	40.3	.8	37.3	.5	.99	.03	.89	.02	243.3	5.4	220.1	4.5
17	25	69	41.5	1.0	37.9	.7	1.06	.03	.95	.02	258.5	6.3	232.7	5.0
18	133	470	40.0	.5	37.4	.5	.99	.02	.89	.02	242.7	4.5	219.5	4.1
19	127	400	41.6	.6	37.7	.5	1.00	.02	.90	.02	247.3	4.5	223.4	4.1
20	45	99	40.9	.8	36.3	.6	1.02	.03	.92	.02	249.9	5.4	224.5	4.5
21	80	123	42.6	.7	38.2	.6	.98	.02	.92	.02	243.8	5.0	227.8	4.5
24	11	62	41.1	1.9	34.6	.8	1.03	.05	.88	.02	252.9	10.9	216.0	5.4
25	48	98	39.7	.8	37.2	.7	.94	.02	.86	.02	232.9	5.4	213.5	5.0
26	49	91	38.2	.8	35.8	.7	1.00	.02	.90	.02	243.5	5.4	221.4	5.0
27	118	272	40.8	.6	37.2	.5	1.02	.02	.90	.02	250.3	4.5	223.0	4.1
28	22	89	41.2	1.1	36.4	.7	.92	.03	.85	.02	230.5	7.2	211.6	5.0
29	16	32	39.7	1.3	37.1	1.0	.98	.04	.90	.03	241.4	7.7	217.3	6.3
30	15	39	40.2	1.2	39.0	.9	.93	.04	.89	.03	232.0	7.2	220.9	5.4
31	2	3	39.2	3.0	32.5	2.7	.87	.08	.97	.07	218.0	16.8	231.7	15.0
33	59	135	40.8	.7	37.6	.6	.99	.02	.92	.02	244.6	5.0	226.0	4.5
34	27	45	41.0	1.0	38.9	.8	.99	.03	.91	.03	245.1	6.3	226.1	5.4
35	72	231	42.2	.7	38.8	.5	.98	.02	.93	.02	243.9	5.0	229.3	4.5
36	12	67	42.5	1.3	36.6	.8	1.04	.04	.91	.03	255.8	8.1	223.1	5.4
39	64	133	37.1	.8	34.0	.6	.94	.02	.85	.02	229.8	5.4	208.4	4.5
40	78	152	39.4	.7	36.8	.5	.98	.02	.92	.02	239.9	5.0	225.7	4.5
41	54	113	39.7	.9	37.2	.7	.98	.03	.91	.02	241.4	5.4	224.8	5.0
42	18	46	40.0	1.4	35.3	.9	1.02	.04	.87	.03	243.5	8.1	213.0	5.9
47	28	70	40.0	1.0	37.0	.7	.95	.03	.84	.02	235.6	5.9	210.0	5.0
48	103	310	40.7	.6	36.2	.5	1.01	.02	.90	.02	247.4	4.5	220.3	4.1
54	74	169	39.6	.7	37.2	.6	.97	.02	.92	.02	238.3	5.0	226.8	4.5
55	15	36	39.9	1.3	36.9	.9	.95	.04	.90	.03	234.9	7.7	222.8	5.9
56	14	33	40.5	1.8	36.9	1.0	1.04	.05	.87	.03	254.2	10.4	215.1	6.3
66	5	49	36.9	2.1	37.9	.8	.97	.05	.87	.03	235.9	11.9	215.9	5.4
67	15	33	39.5	1.3	38.3	1.0	.97	.04	.89	.03	238.2	7.7	219.9	6.3
70	82	133	38.9	.8	37.2	.6	.99	.02	.91	.02	242.9	5.0	224.3	4.5
72	19	37	40.5	1.1	36.1	.9	1.03	.03	.90	.03	252.6	6.8	221.2	5.9
80	33	22	39.4	1.0	36.5	1.1	1.01	.03	.93	.03	246.4	6.3	228.3	6.8
88	28	29	40.7	1.1	35.7	1.1	1.05	.03	.94	.03	256.1	7.2	228.4	6.8
94	39	35	40.7	1.2	35.2	1.0	1.11	.03	.95	.03	269.1	7.2	229.6	6.3
99	15	33	37.7	1.4	37.5	1.2	1.11	.04	.96	.04	265.2	8.1	234.9	7.2

APPENDIX TABLE 7. (CONTINUED)

CF 3/4			BRWT				ADG				WNWT			
			Males		Females		Males		Females		Males		Females	
Sire code	n_1	n_2	μ	SE	μ	SE	μ	SE	μ	SE	μ	SE	μ	SE
1	87	141	40.4	.8	38.2	.7	1.03	.03	.91	.03	251.4	5.9	225.4	5.9
3	6	47	42.7	2.0	38.6	.9	.98	.05	.92	.03	244.1	11.3	226.8	6.3
4	61	110	38.8	.8	35.6	.7	.98	.03	.90	.03	240.3	5.9	220.4	5.9
7	12	20	40.9	2.4	39.8	2.3	1.11	.06	1.00	.06	269.5	13.6	246.0	13.1
9	66	58	39.0	.8	36.7	.9	.99	.03	.93	.03	243.2	6.3	226.9	6.3
10	137	239	39.8	.7	36.6	.6	1.00	.03	.91	.03	244.9	5.4	223.8	5.4
11	76	133	38.4	.8	35.8	.7	.97	.03	.89	.03	236.7	5.9	219.0	5.4
12	65	171	41.7	.8	38.0	.5	1.01	.03	.94	.03	248.2	5.9	232.0	5.4
13	15	16	42.5	1.6	40.5	1.3	1.06	.04	.96	.04	259.4	9.5	237.8	8.1
14	8	23	39.1	1.7	38.5	1.3	.99	.04	.90	.04	242.2	10.0	222.3	8.1
15	18	19	40.2	1.4	36.1	1.3	1.05	.04	.94	.04	254.9	8.6	229.9	8.6
16	7	47	40.9	1.9	38.0	1.2	.98	.05	.90	.04	243.0	11.3	223.6	8.1
18	67	146	38.2	.9	36.7	.7	1.04	.03	.94	.03	252.4	6.3	228.8	5.9
19	147	198	42.6	.7	38.9	.6	.99	.03	.96	.03	245.7	5.9	235.0	5.4
20	29	20	39.5	1.1	37.7	1.2	.98	.04	.90	.04	240.0	7.2	221.6	7.7
21	20	28	41.6	1.1	39.3	1.1	1.03	.04	.92	.04	253.7	7.7	228.2	7.2
25	19	56	42.5	1.1	36.9	.8	1.00	.04	.86	.03	247.1	7.2	214.1	6.3
26	3	42	38.8	2.7	36.6	1.0	1.07	.07	.88	.03	257.8	15.0	217.1	6.3
27	55	110	40.3	.9	37.8	.7	1.10	.03	.94	.03	266.5	6.3	230.8	5.9
28	5	45	39.8	2.2	35.9	1.0	.96	.06	.94	.03	235.8	12.7	229.0	7.2
32	6	17	41.0	2.2	35.3	1.4	1.03	.06	.87	.04	252.3	12.7	214.2	8.6
33	26	48	41.2	1.1	39.2	.9	1.03	.03	.97	.03	253.7	7.2	237.8	6.3
34	8	20	40.9	1.8	39.0	1.2	1.03	.05	.88	.04	251.7	10.4	218.7	7.7
35	19	43	43.0	1.3	37.7	1.0	1.05	.04	.95	.03	259.0	8.1	231.8	6.8
39	25	39	35.3	1.1	34.5	1.0	.96	.03	.89	.03	233.3	7.2	216.2	6.8
40	28	26	38.2	1.0	38.4	1.0	1.02	.03	.96	.03	246.0	6.8	236.1	7.2
41	60	79	38.1	.9	34.2	.9	1.02	.03	.90	.03	248.0	6.8	218.8	6.3
42	18	23	38.0	1.3	33.4	1.2	1.00	.04	.90	.04	243.0	8.1	218.7	7.7
44	18	62	40.8	1.2	37.6	.9	1.01	.04	.86	.03	247.9	7.7	214.9	6.3
48	21	99	41.1	1.1	36.9	1.2	1.07	.04	.93	.03	261.4	7.7	228.7	5.9
51	42	38	42.0	1.0	38.6	1.0	.97	.03	.93	.03	242.0	6.8	229.5	6.8
54	64	98	39.6	.8	38.3	.7	1.04	.03	.94	.03	253.8	5.9	230.3	5.9
56	2	7	37.7	3.0	34.9	1.9	.99	.03	.97	.05	241.2	16.8	233.3	10.0
75	36	44	40.8	1.0	37.2	.9	.98	.03	.87	.03	242.1	6.8	215.5	6.3
76	14	12	38.3	1.4	34.9	1.5	.89	.04	.88	.04	221.0	8.6	215.6	9.0
81	4	39	41.5	2.3	36.5	2.0	.92	.06	.85	.05	230.3	12.7	211.6	11.3
84	21	21	41.0	1.7	37.6	1.6	1.02	.04	.96	.04	251.0	10.0	236.1	9.5
86	7	17	37.5	1.9	39.0	1.4	1.01	.05	.95	.04	244.3	10.9	234.0	8.6
96	26	16	38.8	1.3	36.9	1.5	.93	.04	.90	.04	228.9	8.1	221.4	9.0
98	11	22	39.4	1.5	39.6	1.1	.98	.04	.95	.03	239.9	9.0	234.2	7.2

APPENDIX TABLE 8. LEAST SQUARES MEANS AND S.E. FOR PREWEANING AVERAGE DAILY GAIN (kg/day) FOR THE BULL AND HEIFER PROGENY (MODEL I)

Data set	Sex	
	Bull	Heifer
NCF 1/2	.88±.04 (867)	.78±.04 (3239)
CF 1/2	.85±.06 (280)	.77±.06 (1605)
NCF 3/4	.99±.02 (2541)	.91±.02 (6071)
CF 3/4	1.00±.02 (1359)	.92±.02 (2674)

APPENDIX TABLE 9. LEAST SQUARES MEANS AND S.E. FOR PREWEANING AVERAGE DAILY GAIN (kg/day) FOR EACH AGE OF DAM (MODEL I)

Data set	Age of dam (years) 2	3	4	5 or older
NCF 1/2	.79±.04 (300)	.83±.04 (686)	.86±.04 (716)	.87±.04 (2404)
GF 1/2	.76±.06 (83)	.82±.06 (402)	.83±.06 (289)	.82±.06 (1111)
NCF 3/4	.87±.02 (4671)	.93±.02 (2449)	.99±.02 (1202)	.99±.02 (290)
CF 3/4	.89±.02 (2124)	.95±.02 (1288)	.98±.02 (495)	1.01±.03 (126)

APPENDIX TABLE 10. LEAST SQUARES MEANS AND S.E. FOR PREWEANING AVERAGE DAILY GAIN (kg/day) FOR EACH SEX WITHIN EACH AGE OF DAM (MODEL I)

Data set		Age of dam (years) 2		3		4		5 or older	
NCF 1/2	Males	.83±.04	(44)	.89±.05	(131)	.91±.05	(175)	.92±.05	(517)
NCFL 1/2	Females	.76±.04	(256)	.77±.05	(555)	.81±.05	(541)	.81±.05	(1887)
CF 1/2	Males	.80±.07	(11)	.88±.06	(30)	.87±.06	(51)	.85±.06	(188)
CF 1/2	Females	.73±.06	(72)	.76±.06	(372)	.78±.06	(238)	.79±.06	(923)
NCF 3/4	Males	.90±.02	(1324)	.98±.02	(764)	1.03±.02	(373)	1.05±.02	(80)
NCF 3/4	Females	.84±.02	(3347)	.89±.02	(1685)	.93±.02	(829)	.94±.02	(210)
CF 3/4	Males	.92±.01	(689)	1.10±.02	(455)	1.04±.03	(169)	1.06±.03	(46)
CF 3/4	Females	.86±.02	(1435)	.91±.01	(33)	.93±.01	(326)	.95±.02	(80)

APPENDIX TABLE 11. RESIDUAL AND GENETIC CORRELATIONS (r_g) BETWEEN BIRTH WEIGHT (BRWT), PREWEANING AVERAGE DAILY GAIN (ADG) AND WEANING WEIGHT (WNWT) (MODEL I)[a]

	Data set					
	NCF 1/2			CF 1/2		
	BRWT	ADG	WNWT	BRWT	ADG	WNWT
BRWT	---	.13*	.29*	---	.08*	.21*
ADG	.38*	---	.99*	-.38*	---	.99*
WNWT	.54*	.98*	---	-.16*	.97*	---
	NCF 3/4			CF 3/4		
	BRWT	ADG	WNWT	BRWT	ADG	WNWT
BRWT	---	.12*	.29*	---	.05	.24*
ADG	.56*	---	.98*	.51*	---	.98*
WNWT	.66*	.99*	---	.65*	.98*	---

[a]Residual correlations above the main diagonal genetic correlations below the main diagonal.
*P<.05.

APPENDIX TABLE 12. LEAST SQUARES MEANS AND S.E. FOR WEANING WEIGHT FOR BULL AND HEIFER PROGENY (MODEL I)

Data set	Sex	
	Bull	Heifer
NCF 1/2	220.4± 9.0 (867)	196.8± 8.9 (3239)
CF 1/2	212.2±12.2 (280)	192.6±11.8 (1605)
NCF 3/4	243.4± 4.0 (2541)	221.9± 3.9 (6071)
CF 3/4	245.9± 5.2 (1359)	225.1± 5.1 (2674)

APPENDIX TABLE 13. LEAST SQUARES MEANS AND S.E. FOR WEANING WEIGHT (kg) FOR EACH AGE OF DAM (MODEL II)

Data set	Age of dam (years)							
	2		3		4		5 or older	
NCF 1/2	198.6± 9.1	(330)	206.2± 9.0	(686)	214.6± 9.0	(716)	215.1± 8.9	(2404)
CF 1/2	191.7±11.8	(83)	205.6±12.1	(402)	206.2±11.9	(289)	205.9±11.8	(1111)
NCF 3/4	214.9± 3.9	(4671)	230.1± 3.9	(2449)	241.8± 3.9	(1202)	243.9± 4.2	(290)
CF 3/4	219.2± 5.1	(2124)	234.1± 5.1	(1288)	242.2± 5.2	(495)	246.5± 5.5	(126)

APPENDIX TABLE 14. LEAST SQUARES MEANS AND S.E. FOR WEANING WEIGHT (kg) FOR EACH SEX WITHIN EACH AGE OF DAM (MODEL I)

Data set		Age of dam (years) 2		3		4		5 or older	
NCF 1/2	Males	206.9±10.0	(300)	220.4± 9.3	(131)	226.3± 9.1	(175)	228.0± 9.0	(517)
NCF 1/2	Females	190.1± 9.1	(256)	192.0± 9.0	(555)	202.8± 9.0	(541)	202.2± 9.0	(1887)
CF 1/2	Males	199.9±15.0	(11)	219.7±12.0	(30)	216.8±12.5	(51)	213.2±12.2	(188)
CF 1/2	Females	183.5±11.5	(72)	191.6±11.9	(372)	196.6±11.9	(238)	198.7±11.8	(923)
NCF 3/4	Males	222.8± 3.9	1324)	240.0± 4.0	(764)	253.8± 4.1	(373)	234.4± 4.8	(80)
NCF 3/4	Females	206.9± 3.9	(3347)	208.1± 3.9	(1685)	229.7± 3.9	(829)	230.9± 4.2	(210)
CF 3/4	Males	225.9± 5.2	(689)	244.2± 5.2	(455)	254.3± 5.3	(169)	259.2± 6.3	(46)
CF 3/4	Females	212.5± 5.1	(1435)	224.0± 5.1	(833)	230.1± 5.2	(326)	233.9± 5.8	(80)

APPENDIX TABLE 15. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg), PREWEANING AVERAGE DAILY GAIN (kg/day) AND WEANING WEIGHT (kg) (MODEL II)

	Data set	
	NCF 1/2	NCF 3/4
	1068	3378
Birth weight	36.4±1.5	39.0±.6
Average daily gain	.82±.08	.94±.03
Weaning weight	204.2±17.9	231.7±5.9

APPENDIX TABLE 16. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg) FOR BULL AND HEIFER PROGENY (MODEL II)

	Data set	
Sex	NCF 1/2	NCF 3/4
Bulls	37.6±1.5 (513)	40.2±.6 (1592)
Heifers	35.3±1.5 (555)	37.7±.6 (1786)

APPENDIX TABLE 17. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg) FOR EACH AGE OF DAM (MODEL II)

	Data set	
Age of dam	NCF 1/2	NCF 3/4
2	35.8±1.7 (159)	37.2±.7 (1722)
3	35.3±1.5 (173)	38.7±.7 (1038)
4	37.4±1.5 (213)	39.7±.7 (522)
5 or older	37.2±1.5 (523)	40.3±.8 (96)

APPENDIX TABLE 18. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg) FOR EACH SEX WITHIN EACH AGE OF DAM (MODEL II)

	Data set							
	NCF 1/2				NCF 3/4			
Age of dam	Bulls		Heifers		Bulls		Heifers	
2	36.8±1.7	(78)	34.8±1.7	(81)	38.6± .7	(719)	35.8± .7	(931)
3	36.6±1.6	(93)	34.1±1.6	(80)	40.3± .7	(518)	37.1± .7	(520)
4	38-4±1.6	(89)	36.4±1.6	(124)	40.9± .7	(250)	38.5± .7	(272)
5 or older	38.5±1.5	(253)	35.9±1.5	(270)	41.1± 1.0	(33)	39.4± .8	(63)

APPENDIX TABLE 19. LEAST SQUARES MEANS AND S.E. FOR BIRTH WEIGHT (kg) (BRWT), PREWEANING AVERAGE DAILY GAIN (kg/day) (ADG) AND WEANING WEIGHT (kg) (WNWT) FOR EACH SIRE (MODEL II)

NCF 1/2 Sire code	n	BRWT		ADG		WNWT	
		μ	SE	μ	SE	μ	SE
1	13	32.7	3.9	.71	.13	178.3	28.6
2	23	38.1	2.5	.81	.10	205.0	21.5
3	9	35.2	2.9	.83	.10	206.4	23.1
6	14	39.9	2.3	.95	.09	235.7	20.5
7	20	37.2	2.4	.83	.10	206.8	21.0
9	10	37.2	2.9	.83	.11	208.2	23.1
10	14	37.6	2.6	.85	.10	212.3	20.4
11	60	36.7	2.0	.85	.09	212.7	19.5
12	55	37.6	1.9	.85	.09	212.7	19.1
16	16	37.6	3.4	.77	.11	196.4	25.4
18	38	38.1	2.2	.92	.09	225.9	20.4
19	18	34.5	4.1	.78	.13	194.1	28.6
20	11	40.8	2.9	.90	.10	225.9	23.1
21	38	39.0	2.3	.92	.10	227.1	20.9
23	7	40.8	3.4	.89	.12	224.1	25.4
24	27	34.9	2.6	.77	.10	193.7	21.8
25	18	38.1	2.1	.81	.09	205.0	20.0
26	50	37.2	4.1	.87	.13	215.0	28.6
27	28	36.7	2.0	.84	.09	209.6	19.5
30	13	38.1	2.8	.93	.10	227.7	22.7
33	31	36.7	3.3	.76	.11	191.9	24.9
35	30	35.6	3.3	.76	.11	193.2	24.9
38	30	34.0	3.1	.78	.11	194.6	24.0
39	32	32.2	3.3	.71	.11	179.0	24.9
40	17	37.2	2.6	.85	.10	211.8	21.8
42	17	34.0	2.6	.81	.10	200.0	21.8
44	7	39.5	2.5	1.01	.10	247.2	21.8
45	8	35.4	2.8	.80	.10	199.6	22.7
48	21	34.0	2.5	.80	.10	197.8	21.3
49	59	35.4	3.2	.72	.11	183.3	24.5

APPENDIX TABLE 19. (CONTINUED)

NCF 1/2 Sire Code	n	BRWT μ	BRWT SE	ADG μ	ADG SE	WNWT μ	WNWT SE
54	12	38.6	2.3	.85	.09	213.2	20.4
56	31	36.3	2.1	.88	.09	216.4	20.0
58	28	33.1	3.9	.65	.12	167.4	27.7
59	10	40.4	2.8	.79	.10	202.8	22.7
60	13	30.8	3.9	.73	.03	181.0	28.1
61	14	35.8	3.0	.71	.11	182.3	23.6
62	10	32.7	4.0	.76	.13	187.8	28.1
64	7	34.9	2.9	.82	.10	203.2	23.1
65	17	31.8	3.9	.74	.13	132.8	27.7
69	22	35.4	3.3	.77	.11	193.7	24.9
70	102	36.7	2.9	.87	.10	214.1	23.1
71	11	43.1	3.8	.85	.12	217.1	27.2
72	19	36.7	2.1	.88	.09	218.6	20.0
73	29	33.6	4.3	.73	.14	182.3	29.9
85	9	37.2	3.2	.81	.11	203.7	24.5

APPENDIX TABLE 19. (CONTINUED)

NCF 3/4 Sire Code	n	BRWT μ	BRWT SE	ADG μ	ADG SE	WNWT μ	WNWT SE
1	54	39.5	1.0	.95	.03	233.9	7.2
3	69	40.4	1.2	.98	.04	240.3	8.1
4	70	36.7	1.1	.93	.04	227.6	7.7
6	20	39.9	2.1	.91	.05	227.0	11.9
7	27	39.0	1.4	.87	.04	217.7	9.0
9	96	38.7	1.1	.09	.04	223.2	7.7
10	169	39.5	.9	.95	.03	233.9	6.8
11	276	39.3	.9	.90	.03	223.4	6.8
12	326	40.1	.8	.97	.03	233.7	6.3
14	56	39.8	1.1	.98	.04	239.6	7.2
17	32	41.1	1.4	1.03	.04	252.1	8.6
18	216	39.0	1.0	.92	.03	228.1	6.8
19	281	39.4	1.0	.95	.03	234.4	6.8
20	43	38.5	1.4	.98	.04	240.2	8.6
21	72	39.9	1.0	.98	.03	240.6	7.2
25	54	39.5	1.2	1.33	.04	219.2	8.1
26	40	37.6	1.1	.98	.04	239.3	7.7
27	142	40.1	1.0	.97	.03	238.4	6.8
30	24	39.2	1.2	.91	.04	226.7	8.1
32	49	40.1	1.2	.98	.04	242.4	8.1
33	63	39.8	1.0	.96	.03	235.9	7.2
34	39	38.9	1.9	.90	.05	222.8	10.9
35	140	40.0	1.0	.94	.03	232.6	7.2
36	21	40.3	1.5	.98	.04	240.5	9.0
39	75	37.1	1.2	.38	.04	217.1	8.1
40	76	38.7	1.2	.94	.04	231.1	7.7
41	36	38.4	1.3	.96	.04	236.2	8.6
47	45	38.6	1.1	.89	.04	221.9	7.7
48	142	39.3	.8	.96	.03	235.7	6.8
54	123	38.3	1.5	.96	.04	235.1	9.0
55	19	41.0	1.9	.90	.05	226.7	11.3

APPENDIX TABLE 19. (CONTINUED)

NCF 3/4 Sire Code	n	BRWT μ	BRWT SE	ADG μ	ADG SE	WNWT μ	WNWT SE
66	49	38.9	1.5	.85	.04	215.5	9.5
70	115	38.4	1.4	.97	.04	237.6	8.6
75	18	39.4	2.0	.88	.05	219.9	11.9
77	20	38.7	1.7	.93	.05	229.2	10.4
83	18	36.3	1.6	.93	.04	227.8	10.0
88	44	38.9	2.4	1.01	.06	246.3	13.6
90	21	35.7	1.6	1.00	.04	240.1	10.0
92	19	35.3	2.3	1.03	.06	247.2	12.7
95	23	37.2	1.9	.88	.05	217.7	11.3
97	40	41.1	1.9	.93	.05	232.9	10.9
42	29	37.2	2.4	1.02	.06	246.5	13.6
43	28	43.4	3.4	.88	.09	224.0	18.1
44	34	35.9	2.0	.90	.05	220.6	11.3
45	25	39.4	1.8	.89	.05	222.2	10.9

APPENDIX TABLE 20. LEAST SQUARES MEANS AND S.E. FOR PREWEANING AVERAGE DAILY GAIN (kg/day) FOR BULL AND HEIFER PROGENY (MODEL II)

Sex	Data set NCF 1/2	NCF 3/4
Bulls	.85±.08 (513)	.98±.02 (1592)
Heifers	.78±.08 (555)	.90±.03 (1786)

APPENDIX TABLE 21. LEAST SQUARES MEANS AND S.E. FOR PREWEANING AVERAGE DAILY GAIN (kg/day) FOR EACH AGE OF DAM (MODEL II)

Age of dam	Data set NCF 1/2	NCF 3/4
2	.79±.09 (159)	.87±.03 (1722)
3	.79±.08 (173)	.93±.03 (1038)
4	.84±.08 (213)	.99±.03 (522)
5 or older	.84±.08 (523)	.96±.03 (96)

APPENDIX TABLE 22. LEAST SQUARES MEANS AND S.E. FOR PREWEANING AVERAGE DAILY GAIN (kg/day) FOR EACH SEX WITHIN EACH AGE OF DAM (MODEL II)

	Data set			
	NCF 1/2		NCF 3/4	
Age of dam	Bulls	Heifers	Bulls	Heifers
2	.80±,09 (78)	.78±.09 (81)	.90±.03 (791)	.84±.03 (931)
3	.84±.08 (93)	.73±.08 (80)	.98±.03 (518)	.90±.03 (520)
4	.87±.08 (89)	.82±.08 (124)	1.03±.03 (250)	.95±.03 (272)
5 or older	.88±.08 (253)	.80±.08 (270)	.99±.04 (33)	.93±.03 (63)

APPENDIX TABLE 23. RESIDUAL AND GENETIC CORRELATIONS (r_g) BETWEEN BIRTH WEIGHT (BRWT), PREWEANING AVERAGE DAILY GAIN (ADG) AND WEANING WEIGHT (WNWT) (MODEL II)[a]

	Data set					
	NCF 1/2			CF 1/2		
	BRWT	ADG	WNT	BRWT	ADG	WNWT
BRWT	---	.23*	.39*	---	.13	.30*
ADG	.55*	---	.99*	.33*	---	.99*
WNWT	.66*	.99*	---	.45*	.99*	---

[a]Residual correlations above main diagonal genetic correlations below main diagonal.

*P<.05

APPENDIX TABLE 24. LEAST SQUARES MEANS AND S.E. FOR WEANING WEIGHT (kg) FOR EACH SEX (MODEL II)

Sex	Data set NCF 1/2	NCF 3/4
Bulls	212.2±17.9 (513)	240.4±6.0 (1592)
Heifers	196.2±17.9 (555)	223.1±6.0 (1786)

APPENDIX TABLE 25. LEAST SQUARES MEANS AND S.E. FOR WEANING WEIGHT (kg) FOR EACH AGE OF DAM (MODEL II).

Age of dam	Data set NCF 1/2	NCF 3/4
2	198.1±18.5 (159)	216.0±6.0 (1722)
3	198.1±18.0 (173)	230.8±6.0 (1038)
4	210.6±18.0 (213)	243.1±6.0 (522)
5 or older	210.1±18.0 (523)	237.0±6.5) (96)

APPENDIX TABLE 26. LEAST SQUARES MEANS AND S.E. FOR WEANING WEIGHT (kg) FOR EACH SEX WITHIN EACH AGE OF DAM (MODEL II)

	Data set			
	NCF 1/2		NCF 3/4	
Age of dam	Bulls	Heifers	Bulls	Heifers
2	201.9±18.6 (78)	194.3±18.6 (81)	223.2±6.0 (791)	208.8±6.0 (932)
3	210.8±18.1 (93)	185.4±18.1 (80)	241.2±6.0 (518)	220.4±6.0 (520)
4	216.4±18.1 (89)	204.7±18.1 (124)	252.5±6.1 (252)	233.7±6.1 (272)
5 or older	219.6±18.0 (252)	200.5±18.0 (270)	244.6±7.3 (33)	229.5±6.8 (63)

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Sire by sex and sire by management unit interactions ...