



Early growth and carcass traits of cattle containing Simmental, Angus and Hereford breeding  
by Thomas Joseph Lawlor

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

Montana State University

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**Abstract:**

Performance of 543 (birth) to 153 (carcass) calves raised on 3-year-old and older Hereford dams was analyzed using least-squares procedures. Analyses of variance generally included year, breed group, sex, age of dam, appropriate two-factor interactions and appropriate covariates. Data were collected during the years 1976 through 1979 at the Northern Agricultural Research Center near Havre. Breed groups studied were 50% Simmental-50% Hereford (ISIH), 25% Simmental-75% Hereford (1S3H), Angus-Hereford (AH) and straightbred Herefords (HH).

The ISIH group had the longest gestation length, heaviest birth weight, most calving difficulty, lowest level of calves weaned, greatest growth rate, least fat, highest yield and lowest degree of marbling. Conversely, the AH group differed in all traits except postweaning ADG, where it was similar. The 1S3H and HH groups were similar and intermediate for most traits differing only by the 1S3H group having a longer gestation length and higher preweaning ADG. Least-squares means for the growth traits (kg) birth weight, preweaning and postweaning ADG were 41.4, .884 and 1.17 for 1S1H; 37.9, .856 and 1.08 for 1S3H; 37.2, .858 and 1.18 for AH; 37.9, .813 and 1.12 for HH.

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Signature Thomas J. Lander Jr.

Date August 13, 1980

In memory of my parents,  
Thomas J. and Annette T. Lawlor

EARLY GROWTH AND CARCASS TRAITS OF CATTLE CONTAINING  
SIMMENTAL, ANGUS AND HEREFORD BREEDING

by

THOMAS JOSEPH LAWLOR, JR.

A thesis submitted in partial fulfillment  
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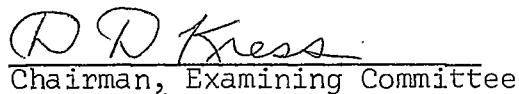
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## ABSTRACT

Performance of 543 (birth) to 153 (carcass) calves raised on 3-year-old and older Hereford dams was analyzed using least-squares procedures. Analyses of variance generally included year, breed group, sex, age of dam, appropriate two-factor interactions and appropriate covariates. Data were collected during the years 1976 through 1979 at the Northern Agricultural Research Center near Havre. Breed groups studied were 50% Simmental-50% Hereford (1S1H), 25% Simmental-75% Hereford (1S3H), Angus-Hereford (AH) and straightbred Herefords (HH). The 1S1H group had the longest gestation length, heaviest birth weight, most calving difficulty, lowest level of calves weaned, greatest growth rate, least fat, highest yield and lowest degree of marbling. Conversely, the AH group differed in all traits except postweaning ADG, where it was similar. The 1S3H and HH groups were similar and intermediate for most traits differing only by the 1S3H group having a longer gestation length and higher preweaning ADG. Least-squares means for the growth traits (kg) birth weight, preweaning and postweaning ADG were 41.4, .884 and 1.17 for 1S1H; 37.9, .856 and 1.08 for 1S3H; 37.2, .858 and 1.18 for AH; 37.9, .813 and 1.12 for HH.

## INTRODUCTION

In recent years, crossbreeding of beef cattle has been utilized to achieve improvements in beef production. Existing variation among breeds allows considerable flexibility in matching germ plasm to the demands of different climatic, nutritional and management situations to most efficiently produce highly palatable and nutritious beef. The choice of breeds to use in crossbreeding should be based on additive breed effects, heterosis and complementarity. Both heterosis and complementarity will depend specifically on the breed combination.

Recommendation for specific breed combinations can be accurately made only when breed combinations have been characterized for the entire spectrum of production traits. The objective of the present study was to examine early growth and carcass traits of beef cattle containing Simmental, Angus and Hereford breeding.

## REVIEW OF LITERATURE

### Crossbreeding Theory

The virtues of crossbreeding have been known for a long time. Charles Darwin (1868) believed that natural selection had produced in us an instinct against incest, and that natural selection was effective in developing this instinct because of the greater survival value of the more vigorous offspring of exogamous matings (Zirkle, 1950). It would be inappropriate to discuss the variations of crossbred vs. straightbred populations without giving mention to the underlying cause of the phenomena involved. It is complementarity and heterosis which animal breeders will most want to capitalize on. Complementarity; a trait of the production unit rather than the individual, is the cumulative effect of interactions among the phenotypes of the sire, dam and produce on the phenotypes of the production system (Fitzhugh et al., 1975).

Heterosis depends on dominance (d) for its occurrence. The concept of dominance can be described as an interaction. The definition of heterosis is, in fact, a definition of interaction. Interaction is the failure of an additive scheme to describe the situation. Thus, the use of dominance serves to illustrate what occurs genetically upon crossing populations (Willham, 1970). The amount of heterosis following a cross between two particular populations depends on the square of the

difference of gene frequency ( $y$ ) between the populations. Therefore heterosis in the  $F_1$  for the single locus situation is  $H_{F_1} = dy^2$ .

If some loci are dominant in one direction and some in the other direction their effects will tend to cancel out, and no heterosis may be observed. The occurrence of heterosis on crossing is therefore, dependent on directional dominance, and the absence of heterosis is not sufficient ground for concluding that the individual loci show no dominance (Falconer, 1960).

More than two alleles does complicate the mathematics somewhat because more than one dominance deviation per locus is possible. But if one allele of several at a locus is favored then this allele can be used along with the rest lumped together, and the rationale for the two-allele system is preserved (Willham, 1970). Heterosis in the  $F_1$  is thus the sum of the joint effects of all the loci, or  $H_{F_1} = dy^2$  unless epistasis is considered to be important.

Genetic divergence can be carried too far. When a deterioration of adaptive epistatic combinations of each breed occurs, then there are problems (Willham, 1970). Falconer (1960) also states the same theory whereby two populations each

adapted to different ways of life are crossed, the crossbred individuals will be adapted to neither, and will consequently be less fit than either of the parent populations. Fortunately for crosses among breeds of domestic animals, epistatic interaction among loci is negligible (Falconer, 1960).

Overdominance is not necessary for heterosis but it is required for the crossbred to exceed both parental types (Mather and Jinks, 1971). Overdominance occurs between two alleles when the heterozygote lies outside the range of the two homozygotes in genotypic value with respect to the trait under discussion. Two types of overdominance can be distinguished, overdominance as a property of a single locus, and overdominance as a property of a segment of a chromosome. Though the evidence of Mendelian genetics suggests that overdominance is not a very common property of genes, many cases are nevertheless known. Overdominance due to pleiotropy is not infrequent. Also what appears to be overdominance with respect to certain characters may be attributed to epistatic interaction (Falconer, 1960).

The genetic consequences of crossbreeding are threefold:

1. The production of heterosis. This depends on the degree of dominance and the square of the gene frequency difference

between the populations crossed and may be positive or negative. 2. The incorporation of desired genes into a population at a faster rate than increasing the frequency of the genes by selection within the population. This depends on the gene frequency difference between populations relative to the gene frequency change possible by selection (Cartwright, 1970 and Willham, 1970). 3. The incorporation of a combination of desirable traits into a population. This depends on the degree of dominance and the gene frequency difference (Willham, 1970).

The  $F_1$  cross exhibits individual heterosis, one half the additive effects of each breed, the maternal effect of the dam breed and any interaction (complementarity) of the new genotype with management or marketing systems. There is no loss of any epistatic superiority of purebreds due to recombination in gametes produced by crossbred parents (Dickerson, 1969, 1973). Differences in heterosis between the sexes of  $F_1$  individuals has been reported by Stonaker (1963), and it was hypothesized that heterosis is influenced by the sex chromosome. Stonaker (1963) called this effect homogametic heterosis. Whatever the reason for this difference in heterosis among sexes, it should be recognized and the sexes analyzed separately.

"Existing breeds of each species are essentially mildly inbred lines. They differ (1) in mean gene frequencies and hence in transmitted effects in breed crosses due to divergence in selection for particular traits and for adaptation to particular environments, as well as to the random drift associated with limited effective population size, (2) in average heterozygosity relative to each other and to the hypothetical population of all possible breed crosses, which also is due largely to varying degrees of inbreeding or of drift toward fixation in gene frequencies and (3) in epistatic combination effects of genes on performance (Dickerson, 1973)."

Heterosis in crossing existing breeds does differ from heterosis in linecrossing within a breed in several very important respects: (1) crossbreeding heterosis represents average improvement in performance over straightbred parents instead of inbred parents, (2) no extra current costs are involved for developing inbred lines and (3) diversity represented among breeds is more likely (than that among inbred lines within a breed) to provide genetic combinations suited to a variety of production - management - marketing situations, including specialized "sire" and "dam" breeds (Moav, 1966; Mason, 1969 and Dickerson, 1973).

Relative efficiency of different methods for utilizing genetic diversity and heterosis depends upon rate of reproduction, magnitude of heterosis, divergence in paternal and maternal performance vs. individual performance and of epistatic deviations from additive-dominant gene effects. Dickerson (1973) recommended methods of crossbreeding for each of these dependencies: 1.) greater heterosis favors specific crossbreeding or synthetics, 2.) lower reproduction rate favors rotational crossbreeding or synthetics rather than specific crossbreeding, 3.) larger breed differences in maternal as compared to individual performance increases advantage of crossing specific "terminal sire" with maternal crossbred dams, 4.) greater recombination loss of parental epistatic superiority in progeny of crossbred parents means less potential role for multibreed synthetics as compared to rotation or specific crossbreeding.

Results indicate that improving additive genotypic value in purebred sires will be approximately as effective in improving crossbred performance as it is in improving purebred performance. Dunn et al. (1970) showed there were no major differences in the pooled sire components of variance for the straightbreds and crossbreds, indicating similar additive

genetic variance in the two groups. Koger et al. (1975) and Dunn et al. (1970) reported high genetic correlations between straightbred and crossbred progeny of purebred sires. Dunn pointed out that there were no significant differences in estimates of heritability between the two groups although higher heritabilities in the crossbreds were noticed. Results in laboratory species also show higher heritabilities for crossbreds (Vinson et al., 1969). Since crosses are less variable, the higher heritability is probably the result of a smaller environmental and a larger genetic contribution to the differences (Stonaker, 1973).

Specific combining ability among sires of the same breed appears to be small and would be difficult to measure effectively (Koger et al., 1975). Low values for sire x breed of dam interaction have been observed by Gregory et al. (1965, 1966 a,b), Dunn et al. (1970) and Koger et al. (1975). Benyshek et al. (1979) did report a significant sire x breed of dam interaction accounting for .3 to 4.0% of the total variation. Therefore it appears heterosis is due to an effect of the breed rather than to sire effects within breeds.

### Gestation Length

Significant breed of sire effects have been reported for gestation length of their calves by Sagebiel et al. (1973), Smith et al. (1976), Deutscher and Slyter (1978), Gregory et al. (1978a) and Anderson et al. (1979). Sire breeds that were characterized by longer than average gestation length tended to sire calves with heavier than average birth weight (table 1) (USDA, 1976). In straightbred Herefords, Sagebiel et al. (1967) and Sagebiel et al. (1973) observed a 285- and 286-day gestation length, respectively. Sagebiel et al. (1967) with straightbred Angus observed a 279-day gestation length. Anderson et al. (1979) with Angus sired crossbred calves also observed a gestation length of 279 days. In Simmental-sired crossbred calves, gestation lengths of 286.2, 285.2 and 286 days have been observed by Smith et al. (1976), Burfening et al. (1978a) and Anderson et al. (1979), respectively.

Male calves have longer gestation lengths than female calves. Differences of .83, 1.9, 1.2, 1.7, 1.1 and 1.05 days have been reported by Sagebiel et al. (1967), Bellows et al. (1971), Cundiff et al. (1974), Smith et al. (1976), Burfening et al. (1978a) and Belcher and Frahm (1979), respectively. The actual birth dates between the sexes may vary more than these

results would indicate. Cundiff et al. (1974) reported average conception date of female embryos was 2.8 days earlier than that of male embryos ( $P < .05$ ). Gestation length was 1.2 days shorter for females than for males ( $P < .05$ ). Thus, females were born 4.0 ( $P < .01$ ) days earlier than males.

Significant breed of dam effects have been reported by Sagebiel et al. (1973), Smith et al. (1976a) and Gregory et al. (1978a). The dam contributes not only by transmitting a sample half of her genes to the calf but also through her maternal ability. Significant maternal effects were found in all three crosses for gestation length among Angus, Hereford and Shorthorns (Sagebiel et al., 1973). This indicates that the fetus is not completely responsible for variation in the gestation period. Gestation lengths for 2, 3, 4 and 5-year-old age of dam subclasses were  $283.5 \pm .2$ ,  $285.0 \pm .3$ ,  $285.4 \pm .3$  and  $285.5 \pm .2$  days, respectively (Smith et al., 1976a). Burfening et al. (1978a) showed a small linear increase in gestation length with increasing age of dam. Bellows et al. (1971) reported a significant positive correlation between condition score and gestation length for Hereford dams.

The high estimates of heritability for gestation length (Sagebiel et al., 1968 and Burfening et al., 1978a), would seem

TABLE 1. -- BREED GROUP MEANS FOR BIRTH TRAITS AND LATE MORTALITY

Breed group <sup>1</sup>	No. <sup>2</sup>	Gest. length (days)	Birth weight (lb.)	Calving difficulty (%)	Mortality <sup>3</sup>	
					Early (%)	Late (%)
HH -----	141	285.5	76.5	18	3.7	4.9
AA -----	166	281.6	68.1	12	4.8	3.8
Heterosis (H by A)		-.6	1.9	-4	-3.0	-2.9
HA + AH ----	375	282.9	74.3	11	1.3	1.5
JH + JA ----	302	281.8	64.6	5	2.6	4.3
SDH + SDA --	232	285.6	78.9	27	6.1	3.4
LH + LA ----	371	288.1	79.8	24	5.1	4.3
CH + CA ----	382	285.9	85.1	34	9.6	5.9
SH + SA ----	399	286.3	83.8	29	6.8	4.3
H dams -----	1106	286.4	79.2	24	5.4	5.0
A dams -----	1262	283.3	74.7	17	4.8	3.0

1

H = Hereford, A = Angus, J = Jersey, SD = South Devon, L = Limousin, C = Charolais, S = Simmental; sire breed is first and dam breed is second.

2

Number of births.

3

Early mortality is within 24 hrs. of birth; late mortality is from 24 hrs. after birth until weaning.

(USDA, 1976)

to indicate that much of the variation is additively genetic and heterosis would, therefore, probably be small. This agrees with the low heterosis values obtained between the Angus and Hereford breeds of .4%, .5%, .15% and -.6% by Sagebiel et al. (1967), Rollins et al. (1969), Sagebiel et al. (1973) and Long and Gregory (1974), respectively. Sagebiel et al. (1967) and Sagebiel et al. (1973) reported more heterosis exhibited in male births. Although heterosis may affect gestation length in a small positive (longer) way the net effect on birth date may be negative (earlier). Gaines et al. (1966) reports calves sired by crossbred bulls were born approximately 1½ weeks earlier than calves sired by purebred bulls. This may be due to hybrid vigor for sexual maturity, libido, semen quality, or to some other cause.

Gestation length accounted for 19% of the variation in birth weight on an overall basis and for 13% of the variation on a within subclass basis (Gregory et al., 1978a). In Simmental-sired calves as gestation length increased, birth weight increased approximately .25 kg/day (Burfening et al., 1978a). This was similar to the respective values of .30 and .20 for Hereford and Angus dams reported by Bellows et al. (1971) and the .25 overall regression reported by Smith et al.

(1976a). However, the increase was not linear. As gestation length increased, birth weight increased at a decreasing rate. The regression of birth weight on gestation length should not be interpreted as an accurate estimate of growth rate during late gestation (Smith et al., 1976). In Hereford cows, the effect of gestation length on birth weight ranked second in importance to precalving body weight of the dam (Bellows et al., 1971).

### Birth Weight

Some of the sources of variation affecting birth weight of calves are year, breed of sire, sex of calf, age of dam, breed of dam and their interactions. Significant year effects were noted by Gregory et al. (1965), Brinks et al. (1967), Sagebiel et al. (1973), Thrift et al. (1978), Gregory et al. (1978b) and Crockett et al. (1979). Sagebiel et al. (1973) reported the year effect could be due to a sire effect since different groups of three sires within each breed were used each year, but a genotype x environment interaction may have been a contributing factor. In Hereford cattle a significant genotype x environment interaction was reported by Burns et al. (1979) showing a 1.2 kg advantage for the local genotypes over the introduced groups.

Burfening et al. (1978c) reported management unit accounted for 24% of the total variation in birth weight, with the sire within management unit accounting for 7.8%. Deutscher and Slyter (1978) reported a significant year by management system (drylot vs. pasture) interaction. Variation in birth weight from year to year may be attributed to environmental factors, genetic factors, changes in management of the herd or their interactions.

Significant breed of sire effect has been reported by Gregory et al. (1965), Pahnish et al. (1969), Turner and McDonald (1969), Reimer and Cobb (1971), Sagebiel et al. (1973), Long and Gregory (1974), Smith et al. (1976a), Anderson et al. (1978), Chapman et al. (1978), Deutscher and Slyter (1978), Gray et al. (1978), Gregory et al. (1978b), Thrift et al. (1978) and Crockett et al. (1979). These differences can be partially summarized as the Simmental and Charolais crosses having the heaviest and Jersey crosses the lightest birth weights. Limousin and South Devon crosses were similar in birth weights and intermediate between Charolais and Simmental crosses and the Hereford-Angus crosses (USDA, 1976).

Differences among Hereford and Angus sires show Hereford-sired calves heavier by .3 kg to 3.8 kg as reported by Gregory et al. (1965), Gaines et al. (1966), Pahnish et al. (1969), Sagebiel et al. (1969), Turner and McDonald (1969), Reimer and Cobb (1971), Laster et al. (1973), Sagebiel et al. (1973), Long and Gregory (1974), Gray et al. (1978), Thrift et al. (1978). Calves by Simmental sires have been shown to be heavier than Hereford and Angus sires (Laster et al., 1973; Smith et al., 1976; Thrift et al., 1978 and Thompson et al., 1979). Birth weights from eight experiments of 50% Simmental calves

had an unweighted average of 37.6 kg ranging from 32.7 to 40.3 kg (Laster et al., 1973; Smith et al., 1976a; Anderson et al., 1978; Burfening et al., 1978b; Burfening et al., 1978c; Chapman et al., 1978; Crockett et al., 1979 and Thrift et al., 1978).

Reports using crossbred bulls are limited, but theoretically a 50% reduction in heterosis is obtained in a backcross. Thrift et al. (1978) reported calves sired by Maine-Anjou x Angus bulls were 1.8 kg heavier ( $P < .01$ ) than the average of calves sired by straightbred bulls. Gaines et al. (1966) reported no difference in birth weight of calves sired by crossbred or purebred bulls.

Within the Hereford breed, line-of-sire can be a significant source of variation when inbred lines are crossed as reported by Flower et al. (1963) and Brinks et al. (1967). Kress et al. (1979) did not find a significant line-of-sire effect. Different results may be due to varying levels of inbreeding or difference in the gene frequencies due to different traits of selection.

A significant sire breed x sex interaction was reported by Smith et al. (1976a). This interaction, although significant, explained less than 1% of the total variation. The effect of

sex of calf on birth weight has numerously been reported. An unweighted average of 10 studies involving crossbred calves show male calves 2.6 kg heavier (Sagebiel et al., 1969; Laster et al., 1973; Long and Gregory, 1974; Smith et al., 1976; Burfening et al., 1978a,b; Chapman et al., 1978; Gray et al., 1978 and Gregory et al., 1978a,b). This value agrees well with a 7-8% advantage for male vs. female calves in Herefords (Koch et al., 1973).

The magnitude of the differences between the sexes for birth weight varies with the age of the dam. In Simmental sired calves, the difference in birth weight between bull and heifer calves was 2.8, 3.2, 3.4 and 3.7 kg respectively, for calves from 2, 3, 4 and 5 to 8-year-old dams (Burfening et al., 1978d). In a crossbreeding experiment by Turner and McDonald (1979) a significant age of dam effect was observed only in the steers.

Thompson et al. (1979) observed that the mean birth weight increased with dam age up to 6 years and tended to decline slowly but erratically after 7 years. Thrift et al. (1978) reported the same trend, with an increase in birth weight from 2 through 5 years of age, remaining constant for the next four (6, 7, 8, 9+) age of dam classifications. Smith et al. (1976a)

reported that the effect of dam age on birth weight was not consistent among breed groups.

This inconsistency may be due to differences in maternal ability among breeds or to the transmitted effects of the breed, which could affect how much variability will be expressed. A maternal effect is a phenotypic value of a dam measurable only as a component part of her offspring's phenotypic value. Not only are the genes of the dam responsible for the maternal effect expressing themselves in the phenotypic value of the offspring, but the dam also contributes a sample half of her genes to the offspring (Willham, 1972). Koch (1972) reported that maternal effects observed from the differences in reciprocal crosses is a real source of variation affecting birth weight. Cundiff et al. (1974) found that progeny of Angus-Hereford cows were 1.3 kg heavier at birth than progeny of the reciprocal cross. Gregory et al. (1965) observed small differences from reciprocal crosses between Hereford, Angus and Shorthorns. Sagebiel et al. (1973) reported no significant maternal effect on birth weight in the Angus, Hereford and Shorthorn breeds.

Breed of dam thus contributes in two ways to the phenotypic value of her offspring (maternal and transmitted effects)

while the sire does so only through his contribution of a sample half of his genes. This contribution by the dam is dependent upon the genetic correlation between direct and maternal effects. If a negative genetic correlation exists between the direct and the maternal effect, the dam either gives her offspring a plus set of genes for the direct effect and a poor maternal effect or vice versa (Koch, 1972 and Willham, 1972). A negative genetic correlation for birth weight has been observed in Herefords by Brinks et al. (1967) and Kress et al. (1979).

Breed of dam has been reported as a significant source of variation in birth weight among crossbred calves (Sagebiel et al., 1973; Smith et al., 1976 and Gregory et al., 1978b). A nonsignificant effect of breed of dam in crossbred calves was reported by Chapman et al. (1978). Within the Hereford breed line-of-dam was reported significant by Brinks et al. (1967), but nonsignificant by Kress et al. (1979).

Heterosis, as indicated by a significant breed of sire x breed of dam interaction, was reported by Gregory et al. (1965), Reimer and Cobb (1971), Long and Gregory (1974), Deutscher and Slyter (1978), Gregory et al. (1978b) and Thrift et al. (1978). Pahnish et al. (1969) found a significant breed of sire x breed

of dam effect only in males. Nonsignificant effects were observed by Sagebiel et al. (1973), Gray et al. (1978) and Chapman et al. (1978).

The range in heterosis for birth weight with the Angus and Hereford breeds is -3% (Crockett et al., 1978) to 3.5% (Gregory et al., 1965 and Reimer and Cobb, 1971). The percentage of heterosis among lines within the Hereford breed has been reported as .1, 3.4, -.7, 2.6 and 3.0 by Flower et al. (1963), Brinks et al. (1967), Burfening and Kress (1973), Humes et al. (1973) and Kress et al. (1979), respectively.

Rollins et al. (1969) pointed out that the larger cross-bred calves at birth may indicate hybrid vigor in embryonic growth and development. Burfening and Kress (1973) suggested that the biggest part of heterosis may be exhibited by the cow for maternal ability rather than by the calf. Thrift et al. (1978) pointed out that the amount of variation accounted for by the breed of sire x breed of dam interaction is relatively small in relation to the amount of variation accounted for by the main effects of breed of sire and breed of dam. This agrees with Gregory et al. (1965) who pointed out the importance of additive genetic variation on birth weight and the relatively high heritability of .42 given by Petty and

Cartwright (1966).

Lactation status of the dam the previous year could affect birth weight of the calf. Pahnish et al. (1969) reported dams that were wet the previous fall produced male calves that were 1.9 kg heavier ( $P < .05$ ) at birth than did dams that were dry the previous fall. Conversely, dams that were dry the previous fall produced heifer calves with a nonsignificant advantage of 1.2 kg in birth weight over cows that were previously lactating. Brinks et al. (1967) reported the effect of lactation status (wet or dry the previous fall) was nonsignificant.

Bellows et al. (1971) found that body weight of the dam exerted a highly significant positive effect on birth weight for both Angus and Hereford cows. This effect ranked first in importance of factors attributed to either the dam or calf and was the most important of variables studied (gestation length was second most important). This would indicate that larger heifers had larger calves through some component of maternal environment. The negative effect of body condition score of the dam on calf birth weight approached significance for Hereford dams. In addition, the positive correlations between weight gains during the first half of gestation and birth weight

were highly significant for Herefords. How these might be related to the influence of maternal environment on birth weight is open to speculation but they could be interpreted to suggest that the partition of nutrients between the dam and fetus is not the same in large and small dams and this results in different fetal growth rates.

Winter supplementation of the dam affected birth weights of Herefords in a drylot (Wyatt et al., 1977). Laster et al. (1974) reported increased levels of energy (4.9, 6.2 or 7.7 kg/head/day) for a 90-day period before the calving season increased ( $P < .01$ ) calf birth weights in straightbred Herefords. Precalving energy level had no effect on the five calf shape measurements taken in this study. The increased calf birth weights were apparently due to an increase in soft tissue rather than an increase in skeletal size.

The regression of day of birth within the calving season on birth weight was a significant source of variation (Turner and McDonald, 1969; Gregory et al., 1978b). This was probably reflecting a season-of-birth effect.

### Calving Difficulty

Interest in birth weight is centered around its association with calving difficulty and later growth performance. Birth weight of the calf has been identified as the most important factor associated with calving difficulty (Bellows et al., 1971; Laster et al., 1973 and Burfening et al., 1978b). Calving difficulty increases of 2.3, 1.6, 2.6 and 1.0% per kilogram increase in birth weight have been observed by Laster et al. (1973), Smith et al. (1976), Burfening et al. (1978a) and Gregory et al. (1978a) respectively. Burfening et al. (1978c) reported a positive genetic correlation of .42 between calving difficulty and birth weight.

The regression of incidence of dystocia on birth weight is curvilinear. Predicted increases in incidence of dystocia at lighter weights have been reported by Gregory et al. (1978a) and Notter et al. (1978a). Gregory et al. (1978a) interpreted the increase in calving difficulty to be the failure of a quadratic regression to describe the effects of lighter birth weight on calving difficulty rather than an increase in calving difficulty being caused by birth weights below a given level. Notter et al. (1978a) interpreted their results as not being of biological significance but as a quadratic approximation of

an asymptotic relationship. Burfening et al. (1978b) describe a threshold effect, where no increase in calving difficulty occurs until a certain birth weight is obtained.

Other factors of the calf which can affect calving difficulty are gestation length and shape of the calf. Bellows et al. (1971) and Burfening et al. (1978a) detected correlations of .06 and .25 respectively, for gestation length and calving difficulty. Calves with longer gestation lengths experienced more calving difficulty (Bellows et al., 1971; Laster et al., 1973; Smith et al., 1976a; and Burfening et al., 1978a). The effect of gestation length on calving difficulty is through its association with birth weight rather than a direct effect of gestation length on calving difficulty (Bellows et al., 1971; Smith et al., 1976a; and Burfening et al., 1978a).

Shape of the calf has been postulated as a possible factor affecting calving difficulty (Brinks et al., 1973; Laster et al., 1973; Smith et al., 1976a; and Burfening et al., 1978c). Laster (1974) found that none of the five calf shape measurements he recorded were significantly related to calving difficulty independent of birth weight. It is apparent then, that increase in birth weight is the primary factor attributing

to calving difficulty, although other factors cannot be neglected.

Breed of sire has been reported as a significant source of variation for calving difficulty by Laster et al. (1973), Laster (1974). Long and Gregory (1974), Deutscher and Slyter (1978), Gregory et al. (1978a,b), Notter et al. (1978a) and Bailey and Moore (1979). Sagebiel et al. (1969) reported that the breed of sire effect was significant only for the males when the sexes were analyzed separately. At least a portion of the difference for incidence of dystocia observed between breed of sire subclasses may be attributed to higher birth weights. Breeds with high mean birth weights also have high mean levels of dystocia (see table 1).

When birth weight was included as a covariate, breed of sire was still significant (Smith et al., 1976; Gregory et al., 1978a; and Notter et al., 1978a). This indicated that factors other than birth weight influenced dystocia. The within breed regressions of dystocia on birth weight can underestimate the between-breed relationship (Notter et al., 1978a). Apparently variation in birth weight within breeds is less closely associated with components of size and structure responsible for dystocia than is variation in birth weight among breeds

(Notter et al., 1978a). Laster (1974) pointed out that genetic or environmental factors that affect skeletal dimensions in calves may have more impact on calving difficulty than factors which produce relatively small differences in weight of soft tissues. It appears then that structural differences of calves between breeds may be an additional factor contributing to dystocia from crossbreeding (Laster et al., 1973; and Smith et al., 1976), although there is no experimental data to support this hypothesis.

Significant breed of dam effects have been observed by Sagebiel et al. (1969), Laster et al. (1973), Laster (1974), Long and Gregory (1974), Smith et al. (1976), Gregory et al. (1978a,b), Notter et al. (1978a) and Bailey and Moore (1979). These results could be due to the transmitted effects of the cow to the calf's genotype responsible for dystocia. It may also be due to cows of different breeds being more susceptible to experiencing calving difficulty. Sagebiel et al. (1969) stated that the correlation between dystocia score and a ratio of birth weight to cow weight indicated that larger calves in relation to the cow have more dystocia. Therefore, cows of smaller breeds when mated to larger sire breeds may be more prone to having calving difficulty.

Bellows et al. (1971a) reported that the pelvic area of the dam exerted a significant negative effect on calving difficulty score in both Hereford and Angus dams. Laster (1974) found that in yearling heifers, pelvic area was influenced by breed of sire ( $P < .01$ ) and breed of dam ( $P < .05$ ). Although Laster (1974) showed pelvic area to be a heritable trait, these two factors accounted for only 18% ( $R^2$ ) of the variation. Gregory et al. (1978b) postulated that certain breeds may be more susceptible to adverse environmental factors contributing to calving difficulty.

The incidence of dystocia is also dependent upon the age of the dam, with younger cows experiencing more dystocia (Brinks et al., 1973; Smith et al., 1976; Burfening et al., 1978b; and Belcher and Frahm, 1979). The primary age difference in regression of incidence of dystocia on birth weight appears to be a leveling off of dystocia at low birth weights in older cows (Burfening et al., 1978a; and Notter et al., 1978a). Laster (1974) found in 2-year-old cows that calf birth weight increases with cow weight at a faster rate than does pelvic area of the cow. Notter et al. (1978a) also observed the same trend in crossbred 2 and 3-year-old cows. the crossbred cows that produced calves with heavier birth

weights tended to have more dystocia, even though the cows were also larger and heavier at the time of calving.

Brinks et al. (1973) calculated the heritability of calving difficulty as a trait of the calf. They obtained values of  $.126 \pm .109$  from 2-year-old cows and  $.069 \pm .022$  from the older cows. Although both estimates are near zero, it appears that the genotype of the calf is somewhat more important in contributing to calving difficulty among 2-year-old cows than in older cows.

The low heritability estimate by Brinks et al. (1973) along with the estimates of 0-10% by Cundiff et al. (1976) and Tong et al. (1976) show the importance of environmental or non-additive genetic effects. Burfening et al. (1978c) reported a heritability value of .32 for calving difficulty. Burfening et al. (1978c) pointed out that in binomially distributed traits, the estimates of heritability are dependent on the frequency. The incidence of calving difficulty was greater in the study by Burfening et al. (1978c) than in the studies cited previously.

Incidence of dystocia is similar between ages of mature cows (Brinks et al., 1973; Laster et al., 1973; and Burfening et al., 1978b). This trend may be explained by the cows attainment of mature skeletal size. Bellows et al. (1971a,b)

and Neville et al. (1978) observed measurable increases in pelvic area from 2 to 3 years of age with a plateau between 36 and 39 months of age. Smith et al. (1976) described a plateauing of dystocia level in 4-year-old cows for all sire breeds except for Charolais and Simmental. Therefore, only in crosses with large sire breeds is increased cow size after 4 years of any advantage. Along with age of dam, parity can have an effect on calving difficulty. Laster et al. (1973) and Notter et al. (1978a) observed more calving difficulty in primiparous 3-year-old cows compared to 3-year-olds calving for the second time.

Evidence presented in the literature pointed to a higher incidence of dystocia with male calves. The range of significant difference between sexes has been reported between 4.9 and 40.2% (Bellows et al., 1971a; Brinks et al., 1973; Laster et al., 1973; Laster, 1974; Long and Gregory, 1974; Smith et al., 1976; Burfening et al., 1978a,b; Gregory et al., 1978a,b; Notter et al., 1978a; and Belcher and Frahm, 1979). Generally, the higher the average level of calving difficulty observed, the greater the difference observed between the sexes (Laster et al., 1973; Smith et al., 1976; Gregory et al., 1978a,b; and Notter et al., 1978a). These differences could be

due to variation in size or shape between the sexes, but sex differences in other factors related to the fetus, such as hormonal differences, can not be ignored (Bellows et al., 1971a).

A significant interaction between sire breed and dam breed would indicate that crossbreeding increases dystocia. Sagebiel et al. (1969), analyzing the sexes individually, reported a significant interaction for heifers. Laster et al. (1973) found a reverse effect, with straightbred female calves having  $6.93 \pm 3.57\%$  higher ( $P < .10$ ) incidence of dystocia than crossbred females. Long and Gregory (1974) found no difference between straightbred and crossbred females. Crossbred male calves do not have significantly larger dystocia scores or more calving difficulties than straightbred male calves (Sagebiel et al., 1969; Laster et al., 1973; and Long and Gregory, 1974).

Several interactions have been reported significant by different observers such as: breed of sire x sex (Laster et al., 1973; and Notter et al., 1978a), breed of sire x age of dam (Laster et al., 1973), breed of dam x age of dam (Laster et al., 1973), breed of dam x sex (Laster et al., 1973 and Burfening et al., 1978b) and age of dam x sex (Laster et al., 1973 and Burfening et al., 1978b). Laster et al. (1973) pointed out

that the breed of sire x sex of calf and breed of sire x age of dam interactions were greater for calves sired by breeds with higher birth weights (Charolais, Simmental, Limousin and South Devon) than for those sired by breeds with lower birth weights (Hereford, Angus and Jersey). This indicates that a factor which affects dystocia is expressed more dramatically when the level of dystocia is high.

Concern over calving difficulty is generated by the losses inflicted upon the cattle industry, due to increases in labor costs, decreased subsequent reproductive performance in cows and a higher incidence of mortality. Laster et al. (1973) reported dystocia significantly decreased incidence of estrus and conception rate. A nonsignificant increase in interval from calving to conception was also observed. Brinks et al. (1973) noted heifers having calving difficulty as 2-year-olds weaned 11% fewer calves of those born the first year and 14% fewer calves per cow exposed the second year. Calves born the second year were an average of 13 days younger and 21 kg lighter at weaning.

### Mortality

Calf losses at or near the time of birth were between 3.7 to 7 times greater ( $P < .01$ ) in calves experiencing dystocia than in those not experiencing dystocia (Laster and Gregory, 1973; Smith et al., 1976; and Notter et al., 1978a). The range in percent mortality between the two groups from the same studies was 8.4 to 15.4. Anderson and Bellows (1967) found that the most common cause of calf mortality at or near the time of birth was injury incurred during difficult or delayed parturition. Laster and Gregory (1973) substantiated Anderson and Bellows (1967) finding. Approximately 90% of the calves dead at birth were attributed to the delay in receiving assistance or the amount of difficulty required to remove the calf. Cundiff et al. (1974) reported calving difficulty had a significant negative influence on postnatal survival to 2 weeks. A nonsignificant 2.2% higher late mortality in calves experiencing dystocia was reported by Notter et al. (1978a). Contrary to these reports, Long and Gregory (1974) found the higher incidence of dystocia in Hereford-sired calves was not associated with lower survival rate.

Sire group influenced ( $P < .01$ ) calf mortality in parturitions involving dystocia, but did not significantly influence

calf mortality in unassisted births (Laster and Gregory, 1973). Breed of sire effects were significant for perinatal mortality when either calving difficulty was included as a fixed effect (Smith et al., 1976a) or with birth weight as a covariate (Gregory et al., 1978a). Notter et al. (1978a) and Gregory et al. (1978a) found significant results for postnatal mortality and calf crop weaned, respectively. Nonsignificant results for breed of sire effects on postnatal mortality and calf crop weaned have been reported by Smith et al. (1976a), Gregory et al. (1978b) and Ellis et al. (1979).

Results for breed of sire effects can vary according to the breeds involved and the ages of the cow. Generally, breed of sire groups that experience the higher levels of calving difficulty also tended to experience higher levels of perinatal mortality and lower levels of calf crop weaned (Gregory et al., 1978a). However, higher incidence of dystocia in Hereford-sired calves (Long and Gregory, 1974) and Brown Swiss-sired calves (Gregory et al., 1978a) was not associated with lower survival rate. Notter et al. (1978a) noted significant breed of sire effects for early mortality (before 72 hours) in 2-year-old cows but not in 3-year-olds.

Age of dam significantly influenced calf losses in studies

by Anderson and Bellows (1967), Koger et al. (1967), Laster and Gregory (1973), Cundiff et al. (1974), Long and Gregory (1974), Brinks and Knapp (1975), Bailey et al. (1977) and Kress et al. (1979). In parturitions involving dystocia, age of dam had no significant influence on calf mortality (Laster and Gregory, 1973). Smith et al. (1976a) reported a nonsignificant age of dam effect for early mortality when calving difficulty was included as a fixed effect, but age of dam was significant for late mortality. Losses from late mortality in calves decreased with increasing age (Smith et al., 1976a). Age of dam effects for late mortality could be due to mothering ability of the cow. Notter et al. (1978a) noted rankings for total and late mortality were similar in 2 and 3-year-olds, and followed rankings for estimated milk production. These results imply that the cow effect on late mortality is associated with the nutrition she provides.

Male calves have lower survival rates at birth, at 72 hours after birth and to weaning than female calves (Anderson and Bellows, 1967; Cundiff et al., 1974; Long and Gregory, 1974 and Gregory et al., 1978a). This difference can be accentuated by the presence of dystocia. Laster and Gregory (1973)

observed higher ( $P < .05$ ) mortality in male calves only with difficult parturitions. The higher level of dystocia associated with male calves does not necessarily mean a higher level of mortality (Gregory et al., 1978b; and Notter et al., 1978a). A contrary report by Bailey et al. (1977) showed males with a higher ( $P < .05$ ) preweaning survival rate.

Notter et al. (1978a) observed that optimum early, late and total survival rates occurred at about one standard deviation above the mean for birth weight. This suggests that initially increasing birth weight is associated with increased calf vigor which can more than compensate for the increased dystocia.

### Preweaning Average Daily Gain

Average daily gain from birth to weaning (ADG) is a function of weaning weight (WW), days of age (DA) and birth weight (BW). If growth is linear with age of calf, then ADG may be expressed as  $\frac{WW - BW}{DA}$ . In this case WW standardized for age of calf may be considered the same trait as ADG, differing from it only because of a scaling factor (Cunningham and Henderson, 1965) or due to differences in birth weight (Sagebiel et al., 1974). The range of .95 to .99 for the genetic correlation of ADG and WW obtained by Petty and Cartwright (1966), Koch et al. (1973), Burfening et al. (1978) and Nelsen and Kress (1979) indicates that a high proportion of the genes affecting ADG also affect WW.

Phenotypic correlation is made up of inheritance, environment or both (Johansson and Rendel, 1968). The high phenotypic correlations of .97 to .98 (Petty and Cartwright, 1966; Koch et al., 1973; Nelsen and Kress, 1979) show that environmental factors influence both ADG and WW in the same direction or not at all. The biology of the situation would indicate that the environmental influence is in the same direction.

Breed of sire significantly affected ADG, adjusted and

actual weaning weights (Gregory et al., 1965; Pahnish et al., 1969; Reimer and Cobb, 1971; Turner and McDonald, 1969; Long and Gregory, 1974; Sagebiel et al., 1974; Smith et al., 1976; Anderson et al., 1978; Deutscher and Slyter, 1978; Gregory et al., 1978a; Gregory et al., 1978b; Peacock et al., 1978; Thrift et al., 1978; and Crockett et al., 1979). Generally, the breed of sire crosses with the lower birth weight tended to have lower ADG and lower adjusted weaning weights (Gregory et al., 1978a). Birth weight can affect weaning weight from two aspects. First from its part-whole relationship and second through its genetic correlation with weaning weight ( $r_g = .33$  to  $.58$ ) (Petty and Cartwright, 1966; Koch et al., 1973; Burfening et al., 1978c and Nelson and Kress, 1979). Birth weight is also genetically associated with ADG but apparently to a lesser extent ( $r_g = .10$  to  $.42$ ).

Although ADG and adjusted weaning weights can be discussed together, differences among breed of sire groups for birth weight can cause a significant source of variation for adjusted weaning weight but not for preweaning ADG (Sagebiel et al., 1974). This is due to a carry over from the breed of sire effect on birth weight.

Actual weaning weights include differences due to age of

the calf. Since calves are weaned at one time, age of calf at weaning becomes an important production trait. Significant ( $P < .01$ ) differences in weaning age have been reported for breed of sire (Peacock et al., 1978). This could be due to differences in reproductive performance or gestation length.

Comparisons between Angus-sired calves and Hereford-sired calves at weaning have been contradictory. Pahnish et al. (1969), Long and Gregory (1974) and Thrift et al. (1978) reported that Angus-sired calves were heavier, whereas Gregory et al. (1965), Gaines et al. (1966), Rollins et al. (1969), Turner and McDonald (1969), Chapman et al. (1970) and Sagebiel et al. (1974) found Hereford-sired calves heavier. Damon et al. (1961) found that Hereford exceeded Angus in general combining ability while contrary results were reported by Long and Gregory (1975) and Smith et al. (1976). Cundiff (1970) summarized crossbreeding results from British breeds and concluded that Hereford's exceeded Angus in transmitted gene effects for growth to weaning but were below in maternal ability. Allenda et al. (1980) reported no difference in additive effect on 205-day weight between the two breeds.

Data presented in the literature show Simmental-sired calves heavier at weaning than Angus and Hereford-sired calves

(Stanford et al., 1974; McAllister et al., 1976; Smith et al., 1976a; Anderson et al., 1978; Chapman et al., 1978; and Thrift et al., 1978) although in some of the studies, the advantage for the Simmental sires was not very great. There appears to be little difference in weaning weights by crossbred bulls vs. purebred bulls (Gaines et al., 1966; and Thrift et al., 1978). Franke (1973), after summarizing the available data concerning use of crossbred bulls, concluded that crossbred sires were not as productive in crossbreeding systems as straightbred sires, although in most cases they could be considered competitive.

Direct comparisons between studies for breed of sire effects must be made with caution. Significant genotype by environment interaction has been observed by Butts et al. (1971) and Burns et al. (1979). These results showed that genetic adaptation to the local environment is an important factor affecting weaning weight. The significant sire breed by dam age interaction reported by Smith et al. (1976) suggested that breeds with greater growth potential responded more to the additional milk production as cow age increased. Not only is the age of dam effect important when comparing breed of sire effects but it also points out the importance of matching the proper nutrient regime with the breed of sire. Comparisons

between breed of sires within a rotational crossbreeding program will depend on the order of rotation (Allenda et al., 1980).

The effects of sex of calf and age of dam on weaning weight has been reported numerously in the literature. The B.I.F. (1976) recommends adjusting sex of calf to a bull or steer basis depending on the majority of male calves in the herd or group for sire, dam and group summaries. Also, the B.I.F. (1976) recommends use of additive correction factors for adjusting weaning weight to a standardized dam age. Rutledge et al. (1971) inferred that the age effects commonly observed make their major contribution through differential milk production associated with the age of dam.

Heterosis has been identified as an important element for increasing weaning weight. A review by Warwick (1968) of 14 studies involving crossbreeding between British breeds indicated a weighted average of 4.6%. For the Hereford and Angus cross, Mason (1966) reported heterosis estimates derived from 11 experiments. The unweighted average of the 11 estimates was 3.6%. The range in estimates reported from these two studies was -3% to 8.8%. These results agree with later reports of 7.2%, 4.3% and 4% obtained from Angus and Hereford

crosses by Long and Gregory (1974), Smith et al. (1976a) and Gray et al. (1978).

Estimates of heterosis have not been as numerous for Continental breeds due to the small number of purebred cows until recent years. The result of Klosterman et al. (1968), Pahnish et al. (1969), Sagebiel et al. (1974), Peacock et al. (1978) and Allenda et al. (1980) showed heterosis estimates obtained from crossing Charolais with British breeds of the same magnitude as British crosses. It is therefore expected that other Continental breeds will also show the same magnitude of heterosis when crossed with British breeds. But the identification of specific combining ability between breeds should not be forgotten as a potential resource for maximizing weaning weight.

Heterosis for weaning weight has been indicated by crossing mildly inbred lines within the Hereford breed (Flower et al., 1963; Brinks et al., 1967; Burfening and Kress, 1973; and Kress et al., 1979). When inbreeding of the dam was taken into account, heterosis estimates for preweaning growth were near zero (Humes et al., 1973; Bailey et al., 1977). Therefore recovery from inbreeding depression probably accounts for most of the crossline heterosis observed.

Crossing breeds or lines not only allows the obtainment of heterosis, but may also provide a solution to the problem of a negative correlation between direct genetic effects and maternal genetic effects on weaning weight as reported by Hohenboken and Brinks (1971), Vesely and Robison (1971) and Kress et al. (1979a,b). The existence of a genetic antagonism between the two components of a character causes any successful attempt in improving one to bring about an unfavorable change in the other (Boudari et al., 1978). Kress et al. (1979b) showed that within the Hereford breed, the sire and dam lines failed to have similar rankings for 205-day weight. This agrees with the result calculated for the male calves by Brinks et al. (1967) and for both sexes by Grapevine et al. (1975). A possible solution is the development of specialized "sire" and "dam" breeds as suggested by Moav (1966), Mason (1969) and Dickerson (1973). This was recommended by Dickerson (1947) in swine, that sows of a line selected for good maternal performance be crossed with boars of a second line selected for rate and economy of post-weaning gains to secure the maximum performance.

Evidence of varying expression of heterosis for preweaning growth in bulls and heifers have been contradictory. Within

the Hereford breed, Stonaker (1963) and Brinks et al. (1967) showed greater crossline heterosis for females than for males. Kress et al. (1979) reported no difference between the sexes whereas Humes et al. (1973) reported a reversal in direction of -3.2% vs. 8.2% in favor of the male calves for preweaning gain.

Results from crossing different breeds exhibit the same contradiction. Sagebiel et al. (1974) and Long and Gregory (1974) observed more heterosis in heifer calves, although in the later it was not significant. Gregory et al. (1965) reported no difference between the sexes, whereas, Pahnish et al. (1969) and Gregory et al. (1978b,c) observed more heterosis in bull calves. Gregory et al. (1978b) noted that the magnitude of heterosis after postweaning growth did not differ between the sexes. Thus, the major difference between sexes was the age at which heterosis was expressed.

### Postweaning Average Daily Gain

The length of the postweaning period can vary according to management systems, i.e., feedlot versus pasture. B.I.F. (1976) recommends a postweaning period of at least 160 days to measure differences in growth rate. It has been shown by the following researchers that breed of sire significantly affects postweaning gain (Gregory et al., 1966b; Sagebiel et al., 1967; Smith et al., 1976b; Gregory et al., 1978b; Drewry et al., 1979; Crockett et al., 1979; and Cundiff et al., 1979). Not only must the test period be long enough but the nutritional regime must be high enough to allow sufficient gains for the expression of genetic differences (Laster et al., 1973). A significant interaction of sire breed with year for postweaning ADG (Gregory et al., 1978b) was interpreted to reflect differential response of different sire breeds to differences in energy density in the diets between the years.

A possible explanation of the sire breed x diet interaction are found in results of Ferrell et al. (1977), Prior et al., (1977) and to a lesser degree Smith et al. (1977). These researchers observed a ration by type interaction, noting that increasing metabolizable energy (ME) increased only fat gain in small type steers, but increased both fat and lean in large

type steers. Since putting on lean meat is more efficient than putting on fat (Smith et al., 1976b), the large type breeds would have an advantage under a high ME nutrient regime. This genotype x ration interaction complicates direct comparisons among studies.

Estimates of the genetic correlations between preweaning and postweaning ADG differ between breeds (Nelsen and Kress, 1979). Nelsen and Kress interpreted their results with the aid of the results by Brown et al. (1972) and Smith et al. (1976c) to represent differences in maturing rate. A higher degree of maturity would place the animal closer to the asymptote of the growth curve. Koch et al. (1976) reported that breeds exhibiting most of their gain preweaning tend to fatten quicker than breeds gaining in both phases. This agreed with Smith et al. (1976d) stating that "animals growing most rapidly during the preweaning interval, in absolute terms and relative to both current and mature weight, tended to grow more slowly at later ages". Growth and degree of maturity tend to be inversely related, that is, faster gaining cattle tend to be less mature than slower gaining cattle at a given age (Franke and Cartwright, 1973).

Koch et al. (1973) noted an important positive environ-

mental correlation between preweaning and postweaning ADG. Feedlot bulls that gained more before weaning for environmental reasons would have a competitive advantage for feed consumption over their genetically comparable mates.

Age of dam effects on postweaning gain are contradictory. Brinks et al. (1962), Burfening and Kress (1973) and Gregory et al. (1978c) reported that there was no residual age of dam effect on postweaning ADG. Age of dam effects opposite of those for weaning weight were reported by Blackwell et al. (1958). They theorized their results to indicate a postweaning compensation for the effects of age of dam on preweaning growth rate. Flower et al. (1963) reported highly significant age of dam effects on postweaning ADG in Hereford heifers. B.I.F. (1976) states that research results show that the age of dam effects on 365-day weight are of approximately the same magnitude as age of dam effects at weaning.

Postweaning ADG can be improved both through selection and systems of mating. Moderate to high heritability estimates of .26 to .65 (Koch et al., 1963; Perry and Cartwright, 1966; Dinkel and Busch, 1973; Nelsen and Kress, 1979) will allow adequate response to selection within breeds. Whereas, heterosis estimates ranging from -5 to 10% (Mason, 1966; Vogt

et al., 1967; Warwick, 1968; Cundiff et al., 1970; Pahnish et al., 1971; Lasley et al., 1973; Long and Gregory, 1975; Drewry et al., 1979), with most estimates positive, will allow additional gain due to crossbreeding.

Within the Hereford breed, crossline heterosis estimates range from -2.6% to 5.3% (Flower et al., 1963; Urick et al., 1968; Burfening and Kress, 1973; Grapevine et al., 1975; Treadway and Curtiss, 1976).

Two important characteristics of heterosis of growth traits are exhibited during the postweaning phase. These are 1.) that the level of heterosis declines with increasing age (Gregory et al., 1966b; Smith et al., 1976a,b; Long and Gregory, 1975; Gregory et al., 1978c) and 2.) that the primary effect of heterosis is to speed up the maturing process (Smith et al., 1976c).

Gregory et al. (1966a,b,c) interpreted the decreasing effect of heterosis on gain in both heifers and steers, and increased fatness of crossbred steers at constant ages as evidence of increased physiological maturing rate due to heterosis. Heterosis for age at puberty (Wiltbank et al., 1966) is certainly evidence for the hypothesis of increased rate of maturing. In addition, Cundiff et al. (1974) reported

that heterosis for maternal ability declined with age. These results act to substantiate the hypothesis that heterosis tends to speed up the maturation process.

### Carcass Traits

Carcass traits can be combined into two groups, quantity or quality. Quantity is estimated by yield grade, indicating differences in estimated yield of boneless, closely trimmed retail cuts from the primal cuts (round, loin, rib and chuck). The prediction equation used for this trait is  $52.56 - 4.95$  (fat thickness over rib eye, [12th rib], in.)  $- 1.06$  (% kidney fat)  $+ .682$  (area of rib eye, sq.in.)  $- .008$  (carcass wt., lb.). Quality of the meat is predicted by marbling, texture, color and firmness (Neumann, 1977).

Breed of sire can affect both carcass quantity and quality (Hedrick et al., 1975; Long and Gregory, 1975; Koch et al., 1976c; Adams et al., 1977; Koch and Dikeman, 1977; Gregory et al., 1978c; Crockett et al., 1979; Koch et al., 1979; Peacock et al., 1979). The difference among breeds indicated that selection has been for different traits. The two major distinctions between selection criteria has been for rate of growth or early maturity.

Cundiff et al. (1971) hypothesized that muscle and bone growth have positive associations with mature size, while higher rates of fat deposition and marbling are associated with earlier maturity and negatively associated with mature size.

Selection for both a high proportion of retail product and marbling is hampered by the opposite genetic association each trait has with fat trim. Evidence from a Hereford selection experiment (Koch, 1978) indicated that selecting for growth rate increased retail product and lowered fat trim percentages. Dinkel and Busch (1973) reported a strong negative genetic relationship between daily gain and carcass fat trim, indicating that genes contributing to rapid growth tend to lower trimmable fat. However, rate of fat deposition has a very high positive genetic correlation with marbling (Cundiff et al., 1971).

The antagonism between quantity and quality at a given carcass weight agrees with the work of Cundiff et al. (1964) and Swiger et al. (1965) who reported large negative genetic correlations between cutability and carcass quality grade (-.80) and between percent retail product and carcass quality grade (-.85), respectively.

The British breeds are characterized as early maturing with a smaller mature size than the Continental breeds. Large growthy breeds have less outside fat and lower degree of marbling than smaller, early maturing breeds when compared at the same age and especially when compared at the same carcass

weight (Neumann, 1977).

The division of breeds into those selected for growth rate or early maturity is not absolute. Gregory et al. (1978d) pointed out that there are important differences among breeds in carcass composition due to the additive effects of genes, independent of breed effects on growth rate or weight. Some breed group differences exist due to differential deposition of subcutaneous, intermuscular, intramuscular and kidney and pelvic fat (Koch et al., 1979). The low positive genetic correlation between carcass growth and marbling (Cundiff et al., 1971) suggests that there are some genes affecting both traits in the same direction.

Variation in weight at which breed groups attain choice marbling is of considerable interest because markets vary as to optimum weights and grades desired (Koch et al., 1979). Characterization of carcass traits among breeds will allow maximum complementarity between breeds. Fitzhugh et al. (1975) defined complementarity as the cumulative effect of interactions among the phenotypes of the sire, dam and produce on the phenotypes of the production system. Therefore, identification of sire, dam and progeny performance under different conditions is essential for maximizing production.

Dinkel and Busch (1973) pointed out that the population of inference is changed depending on whether comparisons are made at a constant age or weight. When age is held constant (Cundiff et al., 1971), variation remaining is interpreted as due to growth rate of various tissues. This removes some variation in weight but not all of it. When weight is held constant, variation remaining reflects differences in proportion or composition (Dinkel et al., 1965). In addition, faster growing animals are adjusted to a younger age than average and slower growing animals are adjusted to an older age than average. They are adjusted to that age at which their carcass weight was the same as the population average.

The age of dam effect starting prenatally and becoming of major proportion during the preweaning period, is maintained during the postweaning period, and is reflected in greater muscle tissue at slaughter (Gregory et al., 1978d).

Gregory et al. (1978d) stated "these results show that increased weight gains associated with maternal effects during the prenatal and postnatal periods and reflected at slaughter do not have the same effect on composition of the increased weight gain as does a higher nutritive environment provided during the growing-finishing period through increased dietary

energy density. Ferrell et al. (1978) and Prior et al. (1977) have shown that increasing the energy density of the diet during the growing-finishing period increases weight gain but that 80% or more of the increased weight gain is due to increased carcass fatness. Thus, it is concluded that either the nutritive environment associated with maternal effects has an influence on composition or increased weight gain different from that of the nutritive environment associated with dietary regime, or that the effect of dietary regimen on composition of increased weight gains may be different if administered before the growing-finishing period".

Reports by Kincaid (1962), Gregory et al. (1966b), Gaines et al. (1967), Klosterman et al. (1968), Hedrick (1970), Urick et al. (1974), Long and Gregory (1975), Koch et al. (1976c), Gregory et al. (1978d) and Drewry et al. (1979) indicated that the effects of heterosis on carcass traits are primarily through effects of heterosis on weight. Thus, there was not a major change in carcass composition associated with the heavier weights of carcasses of crossbred steers. However, results reported by Klosterman et al. (1968) at a weight constant basis and Gregory et al. (1966b), Long and Gregory (1975) and Koch et al. (1979) at an age constant basis showed a

significantly higher percentage of fat in crossbred steers. Since rate of fattening and maturity are generally expected to be positively correlated (Koch et al., 1976c), this may be the result of heterotic effects on physiological maturity.

The final consideration in the production of beef is the level of acceptability by consumers. Among cattle that have been uniformly fed and managed and that are of similar age, marbling is the major determinant of quality grade (Neumann, 1977), but the meat may be similar in palatability (Adams et al., 1977). This agrees with the results of Koch et al. (1979), who indicated that animals of similar age and raised under the same feeding and management conditions, differences in palatability among breed groups were small. It would therefore seem appropriate that most emphasis on selection criteria and systems of mating should be centered on growth and efficiency of lean meat production.

## MATERIALS AND METHODS

### Experimental Design

Research was conducted at the Northern Agricultural Research Center, Havre, Montana during the years 1976 through 1979. Sire breed group comparisons were made on calves sired by Hereford, Angus, 50% Simmental-50% Hereford and Simmental bulls out of straightbred, high quality commercial Hereford cows. These Hereford dams were assigned at random to the sires at breeding time on a within age of dam basis each year. The ages of the dams were 3, 4, 6, 7 and 8 years at the first calving in 1976. Young cows were brought in to the project each subsequent year to provide a 3-year-old subclass.

The experiment was designed to use a large number of sires per breed group to best estimate breed group comparisons. Between 9 to 10 sires were used for each sire breed with the same sires used each year. This number of sires resulted in a small number of progeny per sire ( $\approx 4$ ). Hereford, Angus and Simmental sires were sampled from AI studs. Hereford sires consisted of representatives from both the Horned and Polled Hereford breeds. After an initial analysis showed the Horned and Polled Hereford progeny did not differ significantly in growth traits, the two sire groups were combined.

The 50% Simmental-50% Hereford sires were sons of the purebred Simmental sires to ensure that the genes sampled from the Simmental breed would be similar, on the average, in the crossbred progeny groups of 25% Simmental-75% Hereford and 50% Simmental-50% Hereford. The 50% Simmental-50% Hereford sires were from high quality, performance tested Hereford dams.

Angus and Hereford sires were sampled from the 1975 Curtiss Breeding Service catalog and the Curtiss 1976 Angus bull book. These bulls represent some of the superior individuals of their respective breed. Individual performance ratios for adjusted 205-day weight and adjusted yearling weight were available for 8 of the 10 Hereford bulls and averaged 115 and 114, respectively. All bulls were not included in the calculation of average ratios due to information not being available. Individual performance ratios of the same traits for 6 of the 10 Angus bulls averaged 130 and 117, respectively. The high adjusted 205-day weight ratio for the Angus bulls was partially due to one Angus bull having a 157 ratio. Assuming heritability values of .28 for weaning weight and .58 (final feedlot weight) for yearling weight (Petty and Cartwright, 1966), progeny produced from mating these bulls to a random group of cows from their respective breeds would be expected to

have average ratios of 102 and 104 for Herefords and 104 and 105 for Angus for the respective traits if compared to progeny from all bulls from all herds sampled. These values are representative of their respective breeds only if the assumption that the herds sampled were average for the breed. If these bulls came from genetically superior herds then the above progeny ratios are biased downwards.

Simmental sires were sampled from the 1975 supplement of the National Simmental Sire Summary. Selection was done to acquire a group of bulls which would have an average progeny ratio of approximately 100. Bulls with the necessary information (9 of 9 for weaning weight and 6 of 9 for yearling weight) averaged 100.9 and 99.8 for adjusted 205-day weight and adjusted yearling weight, respectively. The 50% Simmental-50% Hereford bulls were sampled from a commercial herd in Montana. The average individual performance ratio of the 9 crossbred bulls for adjusted 205-day weight and adjusted yearling weight was 96 and 99, respectively.

Therefore, the Angus and Hereford bulls were a more highly selected group and probably represent a group of individuals above the average of their respective breed. Whereas, the Simmental sires were more representative of the Simmental

breed. The 50% Simmental-50% Hereford sires were representative of an average or slightly below average sample of sons of the Simmental sires. Although, this sampling process may be biased in favor of the Angus and Hereford sires, it represented samples of sires available through A.I. at the start of the experiment.

All breed groups were not present in each year (table 2). Due to lack of resources at the beginning of the project, the Angus-Hereford group was not present in 1976. Only Angus-Hereford and straightbred Hereford were present in 1979. Although partial confounding existed, analysis was possible because straightbred Herefords were produced every year.

TABLE 2. DESIGN AND NUMBER OF ANIMALS

Year of birth	Breed group <sup>a</sup>			
	HH	1S3H	1S1H	AH
1976	39 (47) <sup>b</sup>	40 (47)	42 (48)	0 (0)
1977	41 (46)	38 (44)	37 (47)	38 (46)
1978	34 (39)	36 (41)	38 (42)	48 (58)
1979	57 (71)	0 (0)	0 (0)	55 (64)

<sup>a</sup>H= Hereford, S= Simmental, A= Angus, 1S3H= 1 part Simmental and 3 parts Hereford, 1S1H= 1 part Simmental and 1 part Hereford.

<sup>b</sup>First number is number of calves born excluding twins and abnormal calves and number in parenthesis is number of cows bred.

Management of Animals and Experimental Data

All animals were managed the same each year in a manner typical for the Northern Great Plains. Precalving weights of the cows were taken just prior to being moved into the calving pasture at an average time of 27 days before calving. Cows calved in a large pasture where they were kept under surveillance 24 hours per day. Any signs of dystocia were recorded and the necessary assistance was given. Dystocia scores of 1-5 were given describing the type of birth (1= no difficulty, 2= slight difficulty, some assistance required, 3= difficult birth, use of a mechanical calf puller usually required, 4= extreme difficulty, including Caesarean section, and 5= abnormal presentation). Shortly after birth, the calf was weighed and tattooed in both ears, cows' were condition scored and the pair moved as soon as possible into another field. Corn silage and hay were fed during calving and postcalving until adequate grass was available. Gestation length was calculated for all calves using the cow's last date bred from the previous breeding season and birth date of the calf.

Two different summer grazing leases were used during the 4 year project. In 1976 and 1977, a grazing unit was leased on Fort Belknap Indian Reservation, 40 miles south of Harlem,

Montana. In 1978 and 1979, a grazing unit was leased at the Webster Thackeray Ranch approximately 15 miles from the Research Center on the northeast end of the Bear Paw Mountains. Cows and calves were moved to the summer leases in early June with artificial breeding starting shortly afterwards. Weights of both cows and calves were taken just prior to the breeding season at an average age of 60 days for the calves. All cows were artificially bred for 45-days with no cleanup bulls. The use of vasectomized bulls with chinball markers aided in the detection of estrus.

Milk production estimates of a random sample of cows within each breed group was obtained. Tests were taken at two times during lactation; the first in early May at approximately the 30th to 50th day of lactation, and the second in the middle of August at approximately the 130th to 150th day of lactation. The test procedure used was the weigh-suckle-weigh technique. Calves were separated for a designated time period from their dams and then allowed to nurse. Weights of the calves were taken both before and after suckling. The difference between the two weights provided a measurement of the quantity of milk produced. This estimate was then multiplied by an appropriate factor to put all estimates on a 24-hour basis.

Calves were vaccinated for blackleg and malignant edema at branding in early April or May, with a booster shot given later in the year. In early October, calves were weaned and weighed. At this time, wither and hip (1978 and 1979 only) height measurements were taken and a visual condition score was assigned by two people working independently. Condition score is an indicator of condition or fatness ranging from 1 to 9 (1- thinnest, 9- fattest). Calves were vaccinated for infectious bovine rhinotracheitis (IBR) and parainfluenza-3 (PI3) intranasally, treated for grubs and trucked to the Research Center. Weight, height and condition scores were also taken on the cows at weaning.

The present study involved 3 years of postweaning information on the steer calves only. In 1976, 36 steers were trucked directly to the Southern Agricultural Research Center at Huntley, Mt. for feedlot studies. The remaining steers along with the steers from 1977 and 1978 remained at the Research Center. The steers were put in drylots with access to hay and water for 3 to 4 days and then turned into hay fields to graze for 21 days in 1976, 31 days in 1977 and 38 days in 1978. Afterwards, steers were again put in a drylot and started on feed for the final phase of postweaning adjustment

before the start of the postweaning trial. This phase lasted 26 days in 1976, 14 days in 1977 and 7 days in 1978.

Calves were started on feed with 6.8 kg corn silage plus 2.3 kg barley and grass hay ad libitum. A medicated premix was fed to aid in the control of postweaning respiratory disease during the early part of the trial in 1976 and 1978. A 32% (1976) or 30% (1977 and 1978) protein supplement was later included in the ration. Barley was gradually increased until it made up the bulk of the ration. Postweaning ADG was calculated for the first 140 days of the trial.

Steers were group fed with the lightest group in lot 1 and the heaviest group in lot 2. All calves were slaughtered when it was estimated that they had reached low choice grade, however, if steers weighed 477 to 500 kg they were slaughtered regardless of condition. All steers were slaughtered at Rocky Mountain Packing, Havre, Mt., which agreed to take about seven head per week during May and June. Carcass grade and yield data were collected on all carcasses.

Postweaning Trial at Huntley

Thirty-three of the 36 steers shipped to Huntley for feeding trials were steers raised in the present study. The three steers deleted were by Hereford bulls involved in a carcass experiment. One Hereford steer was deleted for the carcass traits because he was slaughtered one month after the others. Comparison of wheat vs. barley as the major concentrate was one of the objectives of this study. Three breed groups were represented: 12 25% Simmental-75% Hereford, 12 50% Simmental-50% Hereford and 9 straightbred Hereford.

The growing phase ration contained wheat or barley fed at the rate of one percent of live weight, .45 kg of a 29% protein supplement containing 150 mg Rumensin per head daily and a full feed of corn silage. At the end of the growing phase (119-days), the steers were adjusted to a finishing ration composed of 65% concentrate and 35% roughage. Rumensin was increased in the ration to 300 mg per head daily for the finishing phase. At the end of the finishing phase (123-days), all steers were slaughtered on July 16, 1977, for a total of 242 days on feed.

### Statistical Analysis

All traits were analyzed by fixed model least-squares procedures as outlined by Harvey (1977). The basic model for all analyses was:

$$Y_{ijklm} = \mu + C_i + B_j + S_k + A_l + (\text{any significant interactions}) + e_{ijklm}$$

where:  $Y_{ijklm}$  = dependent variable of the  $m^{\text{th}}$  calf with the  $i^{\text{th}}$  year,  $j^{\text{th}}$  breed of sire group,  $k^{\text{th}}$  sex and the  $l^{\text{th}}$  age of dam class.

$\mu$  = overall mean

$C_i$  = effect of  $i^{\text{th}}$  year

$B_j$  = effect of  $j^{\text{th}}$  breed group

$S_k$  = effect of  $k^{\text{th}}$  sex of calf

$A_l$  = effect of  $l^{\text{th}}$  age of dam

$e_{ijklm}$  = random error

The effects of years ( $C_i$ ), breed group ( $B_j$ ), sex of calf ( $S_k$ ) and age of dam ( $A_l$ ) were regarded as fixed. The following assumption of random error was made:  $e_{ijklm} = \text{NID}(0, \sigma^2_E)$ . All interactions were included in the initial analysis of a trait and excluded in the final analysis if they proved to be nonsignificant ( $P < .05$ ). Appropriate covariables were included in the model depending on the trait studied. Further

discussion of the covariables used will be included in the results section.

Traits of the calves studied during this experiment were as follows:

Birth traits -- gestation length, birth weight and calving difficulty.

Calf viability -- early and late survival and percentage weaned.

Preweaning and weaning traits -- prebreeding weight (60-days), ADG (birth to weaning), 180-day weight (weight at weaning adjusted linearly to 180 days of age using the calf's own growth rate), condition score, wither height at weaning and weight/height ratio at weaning.

Net kilograms weaned -- using information on all cows bred and on only those cows who produced a calf.

Postweaning ADG -- (140-days) taken at two locations, Havre and Huntley.

Carcass traits -- (Havre station) carcass weight, dressing percentage, yield grade, length, width and area of the rib eye, carcass grade, marbling score, fat thickness over 12th rib and total number of days to reach slaughter criteria.

Carcass traits -- (Huntley station) carcass weight, yield

grade, rib eye area, carcass grade, marbling score and fat thickness over 12th rib.

Traits associated with the cow studied during this experiment were as follows: weights taken precalving and at weaning and amount of change between the two weights; condition scores taken postcalving and at weaning and amount of change between the two scores; weight/height ratio at weaning; two milk production estimates taken on a random sample of cows at approximately the 30th to 50th day of lactation and again on the same cows at the 130th to 150th day of lactation. Traits associated with the cow were analyzed with breed group included as a main effect, which represented the genetic background of the calf the cow was raising (1S1H, 1S3H, AH, HH).

Multiple comparisons between breed groups were made using a linear contrast option available in the program. Significant differences between breed groups were determined by use of a "t" test with degrees of freedom equal to those in the residual mean square (Snedecor and Cochran, 1976).

Records of 551 calves were initially available for analysis. This number was reduced to 543 after excluding three sets of twins and two abnormal calves. All 543 records were analyzed for the birth traits (gestation length, birth weight,

calving difficulty and early mortality). Further edits were made for each trait on the basis of sex (three bulls excluded), type of rearing (three calves grafted and one bummed), sickness (five postweaning) and missing information (31 Angus-Hereford and straightbred Hereford calves were randomly culled before weaning in 1979 due to overstocking). Each trait was analyzed with as many records as possible. Residual correlations were obtained from the analyses with the largest number of observations common to each trait.

Age of dam was grouped into three classifications; 3, 4 and 5+ years of age (mature). This was done to allow calculation of the year x age of dam classification, which would not have been possible due to a missing 5-year-old subclass at the start of the experiment. This type of grouping is recommended by B.I.F. (1976). Sex of calf was divided into heifers and steers.

Net kilograms weaned was analyzed using either all cows bred or only those which produced a calf. The dependent variable was zero if no calf was weaned and 180-day weight or actual weaning weight if a calf was weaned. This trait, as measured, was clearly not normally distributed and tests of significance are therefore only approximate. Records were once

again edited for twins, abnormal calves, rearing of the calf and missing information.

The covariables carcass weight and age of calf were included in all preliminary analyses of carcass traits, except when carcass weight was the dependent variable. Then carcass weight was not included as a covariate. If the covariables were not significant ( $P > .05$ ), they were excluded from the final analysis.

Day of lactation was not included in the analysis of the first milk production trial due to missing information. Year x sex of calf and breed group x sex of calf was not included in any milk production analysis because the small number (9) of steer calves did not permit it.

## RESULTS AND DISCUSSION

### Birth Traits

Analyses of variance for gestation length, birth weight and calving difficulty are presented in table 3. Year was significant only for birth weight. Sex of calf was highly significant for all traits. Steer calves exhibited longer gestation lengths, heavier birth weights and more calving difficulty than the heifer calves. Age of dam effects were important for birth weight and calving difficulty. As age of dam increased, gestation length increased ( $P < .10$ ) accompanied by an increase ( $P < .05$ ) in birth weight (appendix table 1). The opposite trend was observed with calving difficulty, i.e., more calving difficulty was observed in younger dams.

Breed group was highly significant for all traits. Both 50% and 25% Simmentals had longer gestation lengths than straightbred Herefords with all three breed groups having longer gestation lengths than 50% Angus calves (table 4). The gestation length of  $287.5 \pm .6$  days for the 50% Simmentals was longer than that reported by Smith et al. (1976a), Burfening et al. (1978a) and Anderson et al. (1978). Fifty percent Simmentals had the heaviest birth weights and the most calving difficulty, with the other three breed groups being similar. Calves by Simmental sires have been shown to be heavier than

TABLE 3. ANALYSES OF VARIANCE FOR GESTATION LENGTH, BIRTH WEIGHT AND CALVING DIFFICULTY

Source	Birth weight (kg)		Gestation length (days)		Calving difficulty (scores 1, 2, 3) <sup>a</sup>	
	df	Mean squares	df	Mean squares	df	Mean squares
Year (Y)	3	91.53 **	3	35.16	3	.0084
Breed group (B)	3	394.74 **	3	392.14 **	3	.4697 **
Sex of calf (S)	1	975.65 **	1	616.79 **	1	.7079 **
Age of dam (A)	2	308.61 **	2	89.60	2	.7412 **
Birth date						
-lin.	1	321.83 **				
B x S					3	.2364 *
B x A					6	.3491 **
S x A					2	.4256 **
Birth weight						
-lin.					1	.1314
Birth weight						
-quad.					1	.3190 *
Residual	532	18.02	531	33.04	503	.0722

\*\* P<.05.      \*\*\* P<.01.

<sup>a</sup>

1= No difficulty, 2= slight difficulty, some assistance required and 3= difficult birth, use of mechanical calf puller required.

TABLE 4. BREED GROUP MEANS AND STANDARD ERRORS FOR GESTATION LENGTH, BIRTH WEIGHT AND CALVING DIFFICULTY

Breed group	No. of animals	Gestation length (days)	No. of animals	Birth weight (kg)	No. of animals	Calving difficulty (scores 1,2,3) <sup>d</sup>
50% Simmental- 50% Hereford	116	287.5 <sub>±</sub> .59 <sup>c</sup>	117	41.4 <sub>±</sub> .44 <sup>b</sup>	112	1.19 <sub>±</sub> .03 <sup>b</sup>
25% Simmental- 75% Hereford	113	286.9 <sub>±</sub> .60 <sup>c</sup>	114	37.9 <sub>±</sub> .44 <sup>a</sup>	111	1.06 <sub>±</sub> .03 <sup>a</sup>
Angus-Hereford	141	283.2 <sub>±</sub> .55 <sup>a</sup>	141	37.2 <sub>±</sub> .41 <sup>a</sup>	136	1.07 <sub>±</sub> .04 <sup>a</sup>
Hereford	171	284.9 <sub>±</sub> .48 <sup>b</sup>	171	37.9 <sub>±</sub> .36 <sup>a</sup>	167	1.00 <sub>±</sub> .03 <sup>a</sup>

<sup>a,b,c</sup>Means with different superscripts differ ( $P < .05$ ).

<sup>d</sup>1= No difficulty, 2= slight difficulty, some assistance required and 3= difficult birth, use of a mechanical calf puller required.

Hereford and Angus sires (Laster et al., 1973; Smith et al., 1976a; Thrift et al., 1978; Thompson et al., 1979). Birth weight for the 50% Simmental calves was higher than other studies (Laster et al., 1973; Smith et al., 1976a; Anderson et al., 1978; Burfening et al., 1978b; Burfening et al., 1978c; Chapman et al., 1978; Crockett et al., 1979). The longer gestation length and heavier birth weight for the 50% Simmentals can partially be explained by all cows in the present study being 3-year-olds and older.

Only 3% (16) of the 529 calvings with dystocia information required assistance. Within each breed group, 50% Simmentals, required the most assistance 8.9% (10) followed by 25% Simmentals, 50% Angus and Herefords requiring 2.7% (3), 1.5% (2) and .6% (1), respectively. Breed group differences existed even with birth weight included as a covariate. Breed of sire has been reported significant when birth weight was included as a covariate by Smith et al. (1976a), Gregory et al. (1978a) and Notter et al. (1978a). This indicated that factors other than birth weight influenced dystocia.

Birth date was significant for birth weight. Birth weight increased ( $b = .0659$  kg/day) later in the season. Several interactions were significant for calving difficulty, breed group x sex of calf, breed group x age of dam and sex of calf x age of

dam. The 50% Simmental-50% Hereford group was the only breed group which caused an increase in calving difficulty with the males and younger dams (table 5). The sex of calf x age of dam interaction was due to male calves having more calving difficulty in young cows and less in older cows than females. The greater difference observed between the sexes for higher levels of calving difficulty agreed with the work by Laster et al. (1973), Smith et al. (1976a), Gregory et al. (1978a,b) and Notter et al. (1978a).

The quadratic regression of calving difficulty on birth weight was significant. Level of dystocia increased at an increasing rate as birth weight increased, indicating that as birth weight increased above the mean (38.4 kg) the level of dystocia rose rapidly (figure 1). Gregory et al. (1978a) and Notter et al. (1978a) reported a significant linear and quadratic regression of incidence of calving difficulty on birth weight. Their results along with a significant quadratic regression for both incidence and level of dystocia on birth weight in 3- and 4-year-old dams by Burfening et al. (1978b) indicated that both incidence and level of dystocia rise rapidly at the heavier birth weights.

TABLE 5. CALVING DIFFICULTY MEANS AND STANDARD ERRORS FOR THE INTERACTIONS OF BREED GROUP × SEX OF CALF AND BREED GROUP × AGE OF DAM

Breed group <sup>a</sup>	No. of animals	Sex of calf	Age of dam	Calving difficulty (scores 1,2,3)
1S1H	48	heifers		1.08 ± .04
1S1H	64	steers		1.30 ± .04
1S3H	60	heifers		1.04 ± .04
1S3H	51	steers		1.08 ± .04
AH	53	heifers		1.02 ± .05
AH	83	steers		1.11 ± .04
HH	74	heifers		0.99 ± .04
HH	93	steers		1.02 ± .03
1S1H	21		3	1.50 ± .06
1S1H	23		4	1.02 ± .06
1S1H	68		mature	1.05 ± .04
1S3H	19		3	1.14 ± .06
1S3H	23		4	1.01 ± .06
1S3H	69		mature	1.03 ± .03
AH	10		3	1.15 ± .09
AH	33		4	1.04 ± .05
AH	93		mature	1.01 ± .03
HH	21		3	1.00 ± .06
HH	30		4	1.01 ± .05
HH	116		mature	1.01 ± .03

<sup>a</sup> H= Hereford, S= Simmental, A= Angus, 1S1H= 1 part Simmental and 1 part Hereford, 1S3H= 1 part Simmental and 3 parts Hereford.

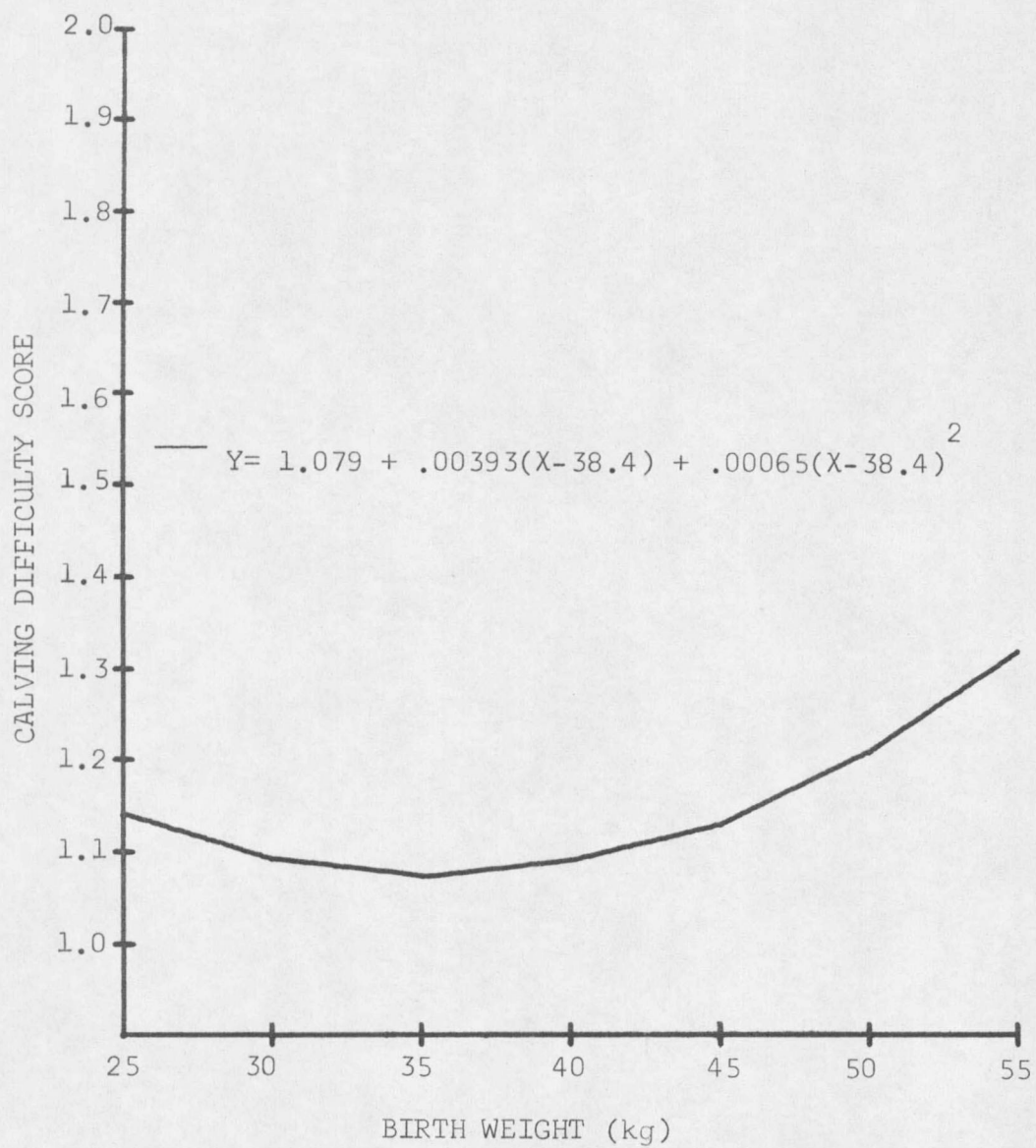


Figure 1. Relationship between birth weight and calving difficulty score

### Calf Viability

Calf viability data were subdivided into early and late survival and percentage of calves weaned of those born. None of the sources of variation were significant for early survival (table 6). Calving difficulty was included as a discrete variable in an analysis, but proved unsuccessful due to the small number (8) of deaths and the high degree of confounding. The residual correlation ( $r = -.39$ ) ( $P < .01$ ) indicates an association between calving difficulty and early survival rates.

Late survival was affected by year, breed group and sex of calf x age of dam interaction (table 7). Year was significant only when birth weight was included as a covariable due to a small change in the year mean square causing it to become significant. The sex of calf x age of dam interaction can be explained by the fact that heifer calves who died were from 3-year-old cows whereas all the steer calves were from 4-year-old or older cows. An unexplained reversal in late survival rate of steer and heifer calves from 4- and  $\geq$  5-year-old dams was reported by Smith et al. (1976a).

Breed group along with the interactions breed group x age of dam and sex of calf x age of dam affected percentage of calves weaned of those born (table 8). The breed group x age

TABLE 6. ANALYSES OF VARIANCE FOR EARLY SURVIVAL (0= DEAD, 1= ALIVE.)

Source	df	Mean squares (birth date covariable)	df	Mean squares (birth weight covariable)	df	Mean squares (no covariate)
Year	3	.0012	3	.0028	3	.0017
Breed group	3	.0105	3	.0122	3	.0078
Sex of calf	1	.0232	1	.0313	1	.0194
Age of dam	2	.0058	2	.0021	2	.0054
Birth date -lin.	1	.0045				
Birth weight -lin.			1	.0158		
-quad.			1	.0020		
Residual	532	.0146	531	.0147	533	.0147

TABLE 7. ANALYSES OF VARIANCE FOR LATE SURVIVAL (0= DEAD,  
1= ALIVE)

Source	df	Mean squares (birth weight covariable)	df	Mean squares (no covariate)
Year	3	.0423 *	3	.0401
Breed group	3	.0443 *	3	.0614 *
Sex of calf (S)	1	.0019	1	.0002
Age of dam (A)	2	.0158	2	.0120
S x A	2	.0584 *	2	.0621 *
Birth weight				
-lin.	1	.0137		
-quad.	1	.0004		
Residual	521	.0162	523	.0161

\* P<.05.

TABLE 8. ANALYSIS OF VARIANCE FOR PERCENTAGE WEANED

Source	df	Percent weaned Mean squares
Year	3	467
Breed group (B)	3	1021 *
Sex of calf (S)	1	163
Age of dam (A)	2	238
B x A	6	886 **
S x A	2	1420 *
Residual	487	308

\* P<.05. \*\* P<.01.

of dam interaction was caused by the low percentage weaned (80%) of the 50% Simmental calves out of 3-year-old cows. A reversal in percentage weaned between steer and heifer calves with age of dam was noticed. Heifers had a weaning rate of 90%, 100% and 99% whereas steers had a weaning rate of 98%, 92% and 94% when raised on 3-year-old, 4-year-old and mature cows, respectively. The sex of calf x age of dam interaction was interesting since neither of the main effects were significant.

Breed group means were tested for differences by two methods. Least-squares analysis was initially used with differences detected by the "t" test. But due to the binomial distribution of the data, differences were also tested by means of the normal deviate "Z" as recommended by R.E. Lund (personal communication). Results from the least-squares analyses are presented in table 9. Fifty percent Simmental calves had the lowest late survival rate with 25% Simmentals intermediate and 50% Angus and straightbred Hereford calves highest. With the "Z" test, only 50% Simmentals and 50% Angus groups differed with the 25% Simmentals and straightbred Herefords intermediate. The 1.01 value for late survival in 50% Angus calves was caused by rounding and was interpreted biologically as a 100%

TABLE 9. BREED GROUP MEANS AND STANDARD ERRORS FOR EARLY AND LATE SURVIVAL<sup>a</sup> AND PERCENTAGE OF CALVES WEANED OF THOSE BORN

Breed group	No. of animals	Early survival	No. of animals	Late <sup>b</sup> survival	No. of animals	Percent weaned (%)
50% Simmental- 50% Hereford	117	.97 ± .01	114	.95 ± .01 <sup>c</sup>	117	91.6 ± 2.0 <sup>c</sup>
25% Simmental- 75% Hereford	114	.99 ± .01	113	.97 ± .01 <sup>c,d</sup>	114	97.4 ± 2.0 <sup>d</sup>
Angus-Hereford	141	.99 ± .01	140	1.01 ± .01 <sup>d</sup>	130	99.5 ± 2.1 <sup>d</sup>
Hereford	171	.98 ± .01	168	.99 ± .01 <sup>d</sup>	144	95.6 ± 1.9 <sup>c,d</sup>

<sup>a</sup>

0= dead, 1= alive.

<sup>b</sup>

From analysis without birth weight included.

<sup>c,d</sup>

Means within column with different superscripts differ (P<.05).

late survival rate. Although breed group was significant for late survival, no apparent reason or trend was available from the information concerning the calves who died (table 10).

The rankings for percentage of calves weaned of those born from the least-squares analysis was slightly different than late survival rate, due to the addition of nonsignificant differences in early survival. Fifty percent Simmental calves also had the lowest percentage weaned but now the straightbred Herefords were intermediate and 25% Simmentals were similar to the 50% Angus. Only the 50% Simmental and 50% Angus groups differed when compared by means of the "Z" test.

Generally, breed groups that experience higher levels of calving difficulty also tended to experience higher levels of perinatal mortality and lower levels of calf crop weaned (Gregory et al., 1978a). Although the 50% Simmentals had higher dystocia scores and lower percentage of calf crop weaned, a significant decrease in early survival was not observed. Smith et al. (1976a) noted that the effect of dystocia on early survival was not the same for all sire breeds. Long and Gregory (1974) and Gregory et al. (1978a) reported higher incidence of dystocia not being associated with

TABLE 10. CHARACTERISTICS OF CALVES THAT DIED BETWEEN 24 HOURS AFTER BIRTH TO WEANING

Breed group <sup>a</sup>	Year	Calving difficulty score	Age of dam	Sex of calf	Remarks
1S1H	1977	5	9	steer	exposure
1S1H	1977	1	7	steer	cause unknown
1S1H	1977	1	3	heifer	cause unknown
1S3H	1977	1	4	steer	cause unknown
1S3H	1978	1	5	steer	bloat
1S1H	1978	1	5	steer	cause unknown
1S1H	1978	1	3	heifer	cause unknown
HH	1979	1	5	steer	bloat
HH	1979	1	4	steer	scours

<sup>a</sup>

S= Simmental, H= Hereford, 1S1H= 1 part Simmental and 1 part Hereford and 1S3H= 1 part Simmental and 3 parts Hereford.

lower survival rates in Hereford-sired and Brown Swiss-sired calves, respectively. Therefore, ability to tolerate higher levels of stress may differ among breeds.

### Preweaning and Weaning Traits

Weights of the calves were taken before the animals were moved to the summer breeding pasture. Average age of the calves at this time was 60 days. Both prebreeding (60-day) weight and average daily gain (ADG) from birth to weaning were an indication of early growth. The 180-day weight was a measure of the weight at weaning adjusted to 180 days of age using the calf's own growth rate.

All main effects were significant for all traits (table 11). The environmental influence on these traits was indicated by the significant year effect. Calves from older dams grew faster than those from young dams and steers grew faster than heifers. Birth date had a significant effect on prebreeding weight ( $b = -.661$  kg/day). Calves born earlier in the year were heavier. Birth date was not important for ADG and 180-day weight, showing that rate of growth was not dependent on when the calf was born. The year x age of dam interaction was highly significant for ADG and 180-day weight and can be explained by the 3-year-old and 4-year-old cows performing poorly in 1976 and 1977, respectively. It is important to note that this was the same group of cows in both years. This suggests that this group of cows may have been less productive than other age groups and that the result may not be merely age related.

TABLE 11. ANALYSES OF VARIANCE FOR PREBREEDING WEIGHT, AVERAGE DAILY GAIN AND 180-DAY WEIGHT

Source	df	Mean squares		
		Prebreeding weight (kg)	Average daily gain (kg/day)	180-day weight(kg)
Year (Y)	3	2881.1 **	.0625 **	2446.8 **
Breed group	3	615.2 **	.1048 **	4888.2 **
Sex of calf	1	2829.4 **	.1602 **	10525.1 **
Age of dam (A)	2	1626.9 **	.1325 **	6655.9 **
Y x A			.0367 **	1233.0 **
Birth date				
-lin.	1	28763.1 **	.0040	20.6
Residual	479 <sup>a</sup>	90.8	.0109	394.6

<sup>a</sup>Degrees of freedom was 472 for ADG and 180-day weight.

\*\*P<.01.

Fifty percent Simmentals were heaviest (table 12) at an average age of 60 days (prebreeding weight). This difference was due to both a heavier birth weight and greater ADG. Although the 25% Simmental and 50% Angus calves did not differ significantly in ADG from the 50% Simmental calves, the difference did approach significance (P<.10). All three groups had greater (P<.01) average daily gain than the straightbred Herefords. The 25% Simmental and 50% Angus calves showed superior early growth compared to the Hereford calves, although this was not significant at the beginning of the breeding

TABLE 12. BREED GROUP MEANS AND STANDARD ERROR FOR CALF PREBREEDING WEIGHT, AVERAGE DAILY GAIN AND 180-DAY WEIGHT

Breed group	No. of animals	Prebreeding weight (kg)	No. of animals	Average daily gain (kg/day)	180-day weight (kg)
50% Simmental- 50% Hereford	111	86.1 ± 1.02 <sup>b</sup>	109	.884 ± .011 <sup>b</sup>	200.5 ± 2.18 <sup>c</sup>
25% Simmental- 75% Hereford	112	81.9 ± 1.01 <sup>a</sup>	111	.856 ± .011 <sup>b</sup>	192.0 ± 2.15 <sup>b</sup>
Angus-Hereford	128	81.6 ± 0.96 <sup>a</sup>	129	.858 ± .011 <sup>b</sup>	191.6 ± 2.02 <sup>b</sup>
Hereford	139	80.8 ± 0.88 <sup>a</sup>	139	.813 ± .010 <sup>a</sup>	184.5 ± 1.87 <sup>a</sup>

a, b, c Means within column with different superscripts differ (P < .05).

season.

Differences in growth up to weaning are reflected in the 180-day weight. Fifty percent Simmentals were heaviest; 25% Simmental and 50% Angus calves were intermediate and similar; and straightbred Hereford calves were lightest.

Data presented in the literature show Simmental-sired calves heavier at weaning than Angus- and Hereford-sired calves (Stanford et al., 1974; McAllister et al., 1976; Smith et al., 1976a; Anderson et al., 1978; Chapman et al., 1978; Thrift et al., 1978). To compare growth up to weaning with other studies found in the literature, ADG was multiplied by 25 (205 - 180 = 25) and added to the 180-day weight for an estimated 205-day weight. The value obtained for 50% Simmentals was 223 kg. This value was above that reported by Chapman et al. (1978) of 201 kg. for calves at an average age of 240 days and Crockett et al. (1979) of 203 kg for calves adjusted linearly to 205 days. In both of these studies the dams were Hereford cows. The 223 kg of the present study was just below the 200-day weight adjusted for birth date and corrected to a steer and a mature age of dam basis of 224 kg (USDA, 1974), who also used Hereford dams. Reports of 197 kg for calves at an average age of 205 days (Thrift et al., 1978) and 223 and 214 kg for 205-

day weight (Burfening et al., 1978a and Burfening et al., 1978c, respectively) have been reported from studies with mixed dam breeds.

To better understand what type of growth was being expressed (i.e., bone, muscle or fat), animals were measured for condition and height. Weight/height ratio was also calculated. Analyses of these three traits are available in table 13. Year, age of dam, year x age of dam interaction and the linear regression on birth date were significant for all traits. Both increasing age of dam and age of calf resulted in increases for all characters. Steers had higher ( $P < .01$ ) condition scores and weight/height ratios but did not differ significantly in height from heifers. Wither height was affected by year x sex of calf and sex of calf x age of dam interactions. Heifer calves were taller in 1976 and grew taller on younger cows (3- and 4-year-olds) than steers.

Subjective condition scores were based on visual (external) indicators of fatness. Examination of breed group means (table 14) showed no differences between breed groups. Differences in wither height at weaning showed 50% Simmentals tallest followed by 25% Simmentals with the 50% Angus and straightbred Herefords being shortest. Although differences

TABLE 13. ANALYSES OF VARIANCE FOR WITHER HEIGHT, WEIGHT/HEIGHT AND CONDITION SCORE

Source	df	Wither height (cm) Mean squares	df	Weight/height (kg/cm) Mean squares	df	Condition score (1-9) Mean squares
Year (Y)	3	83.83 **	3	.3083 **	3	18.000 **
Breed group	3	399.49 **	3	.1380 **	3	1.024
Sex of calf (S)	1	41.48	1	.3555 **	1	7.234 **
Age of dam (A)	2	95.22 **	2	.3883 **	2	8.976 **
Y x S	3	38.69 *	3	.0335		
Y x A	5	27.15 *	5	.0680 *	5	2.629 **
S x A	2	45.71 *	2	.0003		
Birth date -lin.	1	827.63 **	1	2.4272 **	1	47.305 **
Residual	464	10.97	464	.0282	472	.774

\* P<.05. \*\* P<.01.

TABLE 14. BREED GROUP MEANS AND STANDARD ERRORS FOR WITHER HEIGHT, WEIGHT/  
HEIGHT AND CONDITION SCORE

Breed group	No. of animals	Wither height (cm)	No. of animals	Weight/height (kg/cm)	No. of animals	Condition (score) <sup>d</sup>
50% Simmental- 50% Hereford	107	101.3 <sub>±</sub> .37 <sup>c</sup>	107	2.00 <sub>±</sub> .02 <sup>c</sup>	109	6.12 <sub>±</sub> .10
25% Simmental- 75% Hereford	110	99.1 <sub>±</sub> .36 <sup>b</sup>	110	1.95 <sub>±</sub> .02 <sup>a,b</sup>	111	6.14 <sub>±</sub> .09
Angus-Hereford	129	97.5 <sub>±</sub> .34 <sup>a</sup>	129	1.98 <sub>±</sub> .02 <sup>b,c</sup>	129	5.93 <sub>±</sub> .09
Hereford	139	96.8 <sub>±</sub> .31 <sup>a</sup>	139	1.93 <sub>±</sub> .02 <sup>a</sup>	139	5.97 <sub>±</sub> .08

a,b,c Means within column with different superscripts differ (P<.05).

<sup>d</sup>1= thinnest, 9= fattest.

did exist for weight/height ratio between breed groups, interpretation is not straightforward. Long and coworkers (1979) pointed out that the character weight/height ratio can not be interpreted as representative of identical phenomena for all breeds without qualification; differences in weight/height ratio at a specific age may be due to differences in weight or height or differential differences in both. Condition constant weight in cattle has been reported to vary with the 4.3 to 4.6 power of height (Brody, 1945); because of this relationship, interpretation of weight/height ratio is not feasible across large ranges in height. For breeds of similar height, weight/height may be indicative of body type and (or) condition (Long et al., 1979). Based on similar heights, 50% Angus and straightbred Hereford may be compared. The higher weight/height ratio of 50% Angus may be taken to indicate thicker body (endomorphie) type and (or) fatter condition than straightbred Herefords.

Why condition score and weight/height ratio did not agree for the 50% Angus and straightbred Hereford comparison was not apparent. The residual correlation between the two traits was moderately high ( $r = .74$ ). From the residual correlations, it was shown that weight had a higher association with weight/

height ratio than condition score ( $r = .95$  and  $r = .74$ , respectively). Height had a similar association with both weight/height and condition score ( $r = .39$  and  $r = .36$ , respectively).

Net Kilograms Weaned

Since all calves were weaned at one time and because commercial cattlemen are paid by the amount of beef produced, net kilograms weaned is an important-production trait. Net kilograms weaned for cows producing a calf was analyzed (table 15) with actual weaning weights and with weaning weight adjusted for the age of the calf (180-day weight). Year and age of dam were significant for both traits.

Breed groups were significant only for actual weaning weight. Therefore, part of the differences can be explained by age of the calf at weaning. On the basis of productivity per cow producing a calf, Angus-Hereford calves showed a distinct advantage, weaning at least 10 more kilograms of calf per calf born than any other group (table 16).

This trait measures both differences in growth and survival rates, and easily points out the importance of the combination of the two. The 50% Angus calves exceeded in this trait having the second highest preweaning ADG and the highest percentage weaned. The 25% Simmentals were second combining both intermediate growth and survival rates, with 50% Simmentals third, having the highest growth rate but lowest survival rate. Straightbred Herefords were last, having the

lowest preweaning ADG and second lowest survival rate.

TABLE 15. ANALYSES OF VARIANCE FOR NET KILOGRAMS WEANED FOR COWS PRODUCING A CALF (ACTUAL AND 180-DAY WEIGHT)

Source	df	Actual weaning wt. (kg) Mean squares	df	180-day wt. Mean squares
Year	3	7261 **	3	7045
Breed group (B)	3	8194 **	3	3789
Sex of calf	1	589	1	964
Age of dam (A)	2	13564 *	2	10922 **
B x A			6	3424 +
Residual	495	1757	489	1622

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

Net kilograms weaned was also analyzed using information on all cows bred (table 17). Age of dam was the only significant source of variance. Although breed group mean square was not significant, differences among breed groups did exist with rankings similar to when only cows producing a calf was analyzed (table 18). It is important to remember that probability values are only approximate with these traits due to the lack of normality of the data set. Breed group differences using all cows bred represent variation in growth rate, survival rate, sex ratios and reproductive performance.

TABLE 16. BREED GROUP MEANS AND STANDARD ERRORS FOR NET KILOGRAMS WEANED FOR COWS PRODUCING A CALF (ACTUAL AND 180-DAY WEIGHT)

Breed group	No. of animals	Actual weaning weight (kg)	180-day wt. (kg)
50% Simmental- 50% Hereford	117	182.7 $\pm$ 4.3 <sup>a</sup>	181.9 $\pm$ 4.6 <sup>a</sup>
25% Simmental	114	183.0 $\pm$ 4.4 <sup>a</sup>	184.2 $\pm$ 4.6 <sup>a,b</sup>
Angus-Hereford	130	197.8 $\pm$ 4.1 <sup>b</sup>	194.2 $\pm$ 4.8 <sup>b</sup>
Hereford	144	178.4 $\pm$ 3.8 <sup>a</sup>	177.4 $\pm$ 4.3 <sup>a</sup>

<sup>a,b</sup> Means within column with different superscripts differ ( $P < .05$ ).

An accurate estimate of reproductive performance was not clear because of confounding of semen source and breeding group.

TABLE 17. ANALYSES OF VARIANCE FOR NET KILOGRAMS WEANED FOR ALL COWS BRED (ACTUAL WEANING WEIGHT AND 180-DAY WEIGHT)

Source	df	Mean squares	
		Actual weaning wt. (kg)	180-day wt. (kg)
Year	3	10358	10122
Breed group	3	11928	9091
Age of dam	2	20563 *	19806 *
Residual	576	6391	6167

\*  $P < .05$ .

TABLE 18. BREED GROUP MEANS AND STANDARD ERRORS FOR NET KILOGRAMS WEANED FOR ALL COWS BRED (ACTUAL WEANING WEIGHT AND 180-DAY WEIGHT)

Breed group	No. of animals	Actual weaning weight (kg)	180-day wt. (kg)
50% Simmental-50% Hereford	137	151.4 ± 7.6 <sup>a,b</sup>	151.8 ± 7.5 <sup>a,b</sup>
25% Simmental-75% Hereford	131	154.7 ± 7.8 <sup>a,b</sup>	154.2 ± 7.6 <sup>a,b</sup>
Angus-Hereford	156	165.0 ± 7.1 <sup>b</sup>	160.2 ± 7.0 <sup>b</sup>
Hereford	178	143.8 ± 6.5 <sup>a</sup>	142.1 ± 6.4 <sup>a</sup>

<sup>a,b</sup> Means within column with different superscripts differ (P < .05).

Postweaning Average Daily Gain

Postweaning ADG for a 140-day period was collected at two locations. Analyses of variance for data from Havre and Huntley are presented in tables 19 and 20, respectively. At Havre, year and breed group were significant sources of variation. Inclusion of initial weight did not explain the differential growth patterns within either population.

Breed group comparisons are presented in table 21. Fifty percent Simmental and Angus-Hereford grew faster ( $P < .05$ ) than the 25% Simmental group with straightbred Herefords intermediate. Differences in postweaning growth were not significant among breed groups at Huntley.

The 50% Simmental group did not perform as well as reported in three other studies. Adams et al. (1973) reported Simmental-Hereford steers gained faster than both Angus-Herefords and straightbred Herefords which were similar in growth. Steers produced by mating Simmental sires to Hereford and Angus dams outgained Angus-Hereford reciprocal cross calves (Smith et al., 1976b). Anderson et al. (1978) reported Simmental-Angus steers had a greater postweaning ADG than straightbred Angus steers.

The 25% Simmental mean was much lower than expected.

Theoretically, it should lie between the 50% Simmentals and the straightbred Herefords, providing complementarity was minimal. The deviation could be due to sampling error because the post-weaning study was performed on a randomly selected subgroup of the total population. The genes passed onto the 25% Simmental calves may not have been of equal genetic value to either straightbred population. This could be explained by the fact that each animal receives a sample half of each parent's genes. Another possibility as proposed by Dickerson (1969, 1973) is the loss of any epistatic superiority from the straightbreds due to recombination in gametes produced by crossbred parents.

TABLE 19. ANALYSIS OF VARIANCE FOR POSTWEANING AVERAGE DAILY GAIN (HAVRE 140-DAYS)

Source	df	Mean squares	df	Mean squares
Year	2	.1111 *	2	.1046 *
Breed group	3	.0814 *	3	.0770 *
Age of dam	2	.0119	2	.0082
Initial weight				
-lin.	1	.0131		
Residual	143	.0248	144	.0247

\*  $P < .05$ .

TABLE 20. ANALYSIS OF VARIANCE FOR POSTWEANING AVERAGE DAILY GAIN (HUNTLEY 140-DAYS)

Source	df	Mean squares
Treatment <sup>a</sup>	1	.0265
Breed group	2	.0313
Age of dam	2	.0133
Initial weight -lin.	1	.1151
Residual	26	.0346

<sup>a</sup>Wheat vs. barley as the concentrate.

TABLE 21. BREED GROUP MEANS AND STANDARD ERRORS FOR 140 DAYS POSTWEANING GAIN (KG/DAY)

Breed group	No. of animals	Havre	No. of animals	Huntley
50% Simmental- 50% Hereford	46	1.17 ± .025 <sup>b</sup>	12	1.31 ± .056
25% Simmental- 75% Hereford	36	1.08 ± .029 <sup>a</sup>	12	1.24 ± .055
Angus-Hereford	27	1.18 ± .034 <sup>b</sup>		
Hereford	43	1.12 ± .027 <sup>a,b</sup>	9	1.35 ± .070

<sup>a, b</sup>Means with different superscripts differ (P < .05).

Carcass Traits

Analyses of variance for measurements of carcass quantity are presented in table 22 and for rib eye area and its component parts, length and width in table 23. Rib eye area is an indicator of muscling or meatiness in the entire carcass (Peacock et al., 1979). Year was significant for all traits. Breed group was significant for all traits except dressing percentage and width of rib eye when carcass weight was included as a covariate. Carcass weight was an important covariable for rib eye area and its components. Inclusion of carcass weight decreased the mean squares for breed group. Since there were no significant differences among breed groups for dressing percentage, differences in carcass weight can be interpreted as being due to having been slaughtered at different weights.

Even with differences in carcass weight, both yield grade and rib eye area should provide an unbiased estimate of meatiness in the carcass because yield grade includes differences due to carcass weight in its calculation and analysis of rib eye area included carcass weight as a covariate. By including carcass weight as a covariate, variation remaining reflects differences in proportion or

composition (Dinkel et al., 1965). Both indicators of "meatiness" in the carcass ranked the breed groups the same (tables 24 and 25). Fifty percent Simmentals had the largest rib eye area and highest yield. The 25% Simmentals, 50% Angus and straightbred Herefords had similar rib eye areas but differed in yield. Twenty-five percent Simmental and straightbred Hereford steers were similar and intermediate in yield of primal cuts with 50% Angus steers being lowest.

Adams et al. (1973) reported Simmental-Hereford steers had larger rib eye areas than Angus-Hereford and straightbred Hereford steers but were similar in dressing percent and USDA yield grades. Martin et al. (1980) with Simmental-Angus and straightbred Angus steers reported a significant difference for rib eye area but no difference in USDA cutability. No difference in either rib eye area or cutability was observed by McAllister et al. (1976) for Simmental- and Polled Hereford-sired steers out of Angus-Holstein cows. However, rib eye area/100 kg carcass weight did differ ( $P < .05$ ) for Simmental- and Polled Hereford-sired calves with 50% Simmentals having the larger value. Although not significant in the above studies, Simmental-sired steers had the highest cutability ranging from .3 to 1.4% higher than the aforementioned breed groups.

TABLE 22. ANALYSES OF VARIANCE FOR CARCASS WEIGHT, DRESSING PERCENTAGE AND YIELD GRADE

Source	df	Carcass weight (kg) Mean squares	df	Dressing percentage (%) Mean squares	df	Yield grade (1-5) <sup>a</sup> Mean squares
Year	2	4104.8 **	2	8.214 *	2	5.623 **
Breed group	3	2265.1 **	3	2.686	3	3.001 **
Age of dam	2	319.5	2	.791	2	.178
Residual	145	237.1	145	2.487	145	.257

<sup>a</sup>  
1= highest, 5= lowest.  
\* P<.05. \*\* P<.01.

TABLE 23. ANALYSES OF VARIANCE FOR LENGTH, WIDTH AND AREA OF THE RIB EYE

Source	Length (mm)		Width (mm)		Area (cm <sup>2</sup> )							
	df	Mean squares <sup>a</sup>	df	Mean squares	df	Mean squares <sup>a</sup>	df	Mean squares				
Year	2	261.51 **	2	186.24 *	2	68.40 *	2	187.73 **	2	141.3 *	2	445.0 **
Breed	3	353.06 **	3	540.96 **	3	28.63	3	76.55 **	3	134.9 *	3	421.1 **
Age of dam	2	63.52	2	110.56	2	25.78	2	16.16	2	28.9	2	18.2
Carcass wt (linear)	1	1271.83 **			1	184.58 **			1	1708.5 **		
Residual	145	41.59	146	50.07	145	14.58	146	15.80	145	22.5	146	46.6

<sup>a</sup>Carcass weight included as covariate.  
\* P < 0.05. \*\* P < 0.01.

TABLE 24. BREED GROUP MEANS AND STANDARD ERRORS FOR CARCASS WEIGHT, DRESSING PERCENTAGE AND YIELD GRADE.

Breed group	No. of animals	Carcass weight(kg)	Dressing percentage(%)	Yield grade (1-5) <sup>d</sup>
50% Simmental- 50% Hereford	46	254.5 ± 2.4 <sup>c</sup>	55.1 ± .25	2.1 ± .1 <sup>a</sup>
25% Simmental- 75% Hereford	36	244.8 ± 2.8 <sup>a,b</sup>	54.8 ± .29	2.4 ± .1 <sup>b</sup>
Angus-Hereford	27	251.3 ± 3.4 <sup>b,c</sup>	55.3 ± .34	2.8 ± .1 <sup>c</sup>
Hereford	44	238.0 ± 2.6 <sup>a</sup>	54.7 ± .27	2.5 ± .1 <sup>b</sup>

<sup>a,b,c</sup> Means within column with different superscripts differ (P<.05).

<sup>d</sup> 1= highest, 5= lowest.

TABLE 25. BREED GROUP MEANS AND STANDARD ERRORS FOR LENGTH, WIDTH AND AREA OF THE RIB EYE

Breed group	No. of animals	Length (mm)	Width (mm)	Area (cm <sup>2</sup> )
50% Simmental- 50% Hereford	46	145.6 ± 1.0 <sup>c</sup>	60.22 ± .62 <sup>b</sup>	75.2 ± 1.0 <sup>b</sup>
25% Simmental- 75% Hereford	36	143.1 ± 1.2 <sup>b,c</sup>	58.36 ± .70 <sup>a</sup>	71.8 ± 1.1 <sup>a</sup>
Angus-Hereford	27	137.5 ± 1.4 <sup>a</sup>	60.16 ± .84 <sup>a,b</sup>	70.8 ± 1.3 <sup>a</sup>
Hereford	44	141.7 ± 1.2 <sup>b</sup>	58.86 ± .68 <sup>a,b</sup>	71.7 ± 1.1 <sup>a</sup>

a, b, c

Means within column with different superscripts differ (P<.05).

Koch et al. (1976) after adjusting to a hot carcass weight of 288 kilograms reported Simmental-Hereford steers had both larger longissimus muscle areas and better yield grades than Angus-Hereford and straightbred Hereford steers. The Angus-Hereford steers had larger rib eyes but were similar in yield grade with the straightbred Herefords.

Analyses of variance for indicators of carcass quality are presented in table 26. Year was significant for both carcass grade and marbling score. Age of calf at slaughter was a significant source of variation for both quality scores. Carcass grade and marbling score increased with increasing age of the calf ( $b = .0107$  units/day and  $b = .0204$  units/day, respectively). Koch et al. (1976) reported for a multibreed population, including those under study here, that within breed groups, marbling score increased an average of  $.028 \pm .003$  units per day during the last 60 days on feed. Regression coefficients were homogeneous across breed groups (Koch et al., 1976).

Although breed group was only significant for carcass grade, significant differences between 50% Simmental and Angus-Hereford steers did exist for marbling score (table 27). Both 50% Angus and straightbred Hereford steers had higher carcass

grades than 50% Simmentals with 25% Simmentals being intermediate. Breed groups ranked the same for both traits. Since degree of marbling is one of the primary factors influencing carcass grade, similar rankings would be expected. The residual correlation of .86 between carcass grade and marbling score supports the strong association between the two traits.

Adams et al. (1973) reported no difference between Simmental-Hereford, Angus-Hereford and straightbred Hereford steers for marbling score and USDA quality score. Martin et al. (1980) reported no difference in marbling score for Simmental-Angus vs. straightbred Angus steers. No difference in marbling score or quality grade was observed by McAllister et al. (1976) for Simmental- and Polled Hereford-sired steers out of Angus-Holstein cows.

Interpretation of these studies should not be made without some mention of their experimental methods. The experimental design of Adams et al. (1973) and Martin et al. (1980) required steers be slaughtered when they reached the estimated USDA slaughter grade of low choice and choice, respectively. Therefore, no difference in carcass quality would be expected to be present among breed groups. Lack of a difference cannot be interpreted to represent a lack of genetic differences

among breed groups. None of the studies in the previous paragraph take into account variation due to age. When age is held constant, variation remaining is interpreted as due to growth rate of various tissues (i.e. fat, lean or bone) (Dinkel and Busch, 1973). As mentioned earlier, marbling increases with increased length of the feeding period.

Koch et al. (1976) after adjusting to a starting age of 240 days and 217 days on feed reported Simmental-Hereford and straightbred Hereford steers had both lower quality grades and lower marbling scores than Angus-Hereford steers. Simmental-Hereford steers had a lower quality grade than straightbred Herefords.

Gregory et al. (1978d) reported important differences among breeds in carcass composition due to the additive effects of genes, independent of breed effects on growth rate or weight.

Residual correlations pooled within breed groups only show a strong association between fat thickness and yield grade ( $r = .78$ ). Residual correlations between fat thickness and rib eye area, marbling score and carcass grade were  $-.14$ ,  $.15$  and  $.13$ , respectively. Therefore, the association of fat thickness with other traits may not be that strong among individuals

within breed group.

Other carcass traits analyzed (table 28) were average fat thickness over the 12th rib and age at slaughter to reach whichever came first, low choice grade or 477 to 500 kg. Age of dam was significant for age at slaughter, with steers from 3-, 4-year-old and mature cows being 438.7, 429.5 and 427.1 days old, respectively. Apparently, the age of dam effect starting prenatally and becoming of major proportion during the preweaning period was maintained during the postweaning period and was reflected in the time required to reach slaughter criteria.

Breed group was highly significant for fat thickness. Rankings of breed groups for fat thickness (table 29) were similar to the quality traits of carcass grade and marbling score but exactly opposite to the quantity traits of yield and rib eye area. The antagonism between quantity and quality agrees with the work of Cundiff et al. (1964) and Swiger et al. (1965) who reported large negative genetic correlations between cutability and carcass grade (-.80) and between percent retail product and carcass quality grade (-.85), respectively.

Results from a preliminary analysis showed carcass weight not to be important for fat thickness, marbling score and

TABLE 26. ANALYSES OF VARIANCE FOR CARCASS GRADE AND MARBLING SCORE

Source	df	Mean squares	
		Carcass grade <sup>a</sup>	Marbling scores <sup>b</sup>
Year	2	4.982 **	15.334 *
Breed group	3	2.289 *	6.788
Age of dam	2	.304	1.711
Age of calf			
-lin.	1	6.749 **	24.408 **
Residual	144	.820	3.271

<sup>a</sup> 17= good, 18= high good, 19= low choice.

<sup>b</sup> 5= slight +, 6= small -, 7= small.

\* (P<.05), \*\* (P<.01).

TABLE 27. BREED GROUP MEANS AND STANDARD ERRORS FOR CARCASS GRADE AND MARBLING SCORE

Breed group	No. of animals	Carcass grade <sup>c</sup>	Marbling score <sup>d</sup>
50% Simmental- 50% Hereford	46	18.2 ± .1 <sup>a</sup>	5.5 ± .3 <sup>a</sup>
25% Simmental- 75% Hereford	36	18.5 ± .2 <sup>a,b</sup>	5.9 ± .4 <sup>a,b</sup>
Angus-Hereford	27	18.7 ± .2 <sup>b</sup>	6.6 ± .4 <sup>b</sup>
Hereford	44	18.6 ± .1 <sup>b</sup>	6.0 ± .3 <sup>a,b</sup>

<sup>a,b</sup> Means within column with different supercripts differ (P<.05).

<sup>c</sup> 17= good, 18= high good, 19= low choice.

<sup>d</sup> 5= slight +, 6= small -, 7= small.

TABLE 28. ANALYSES OF VARIANCE FOR FAT THICKNESS AND FINAL AGE AT SLAUGHTER

Source	df	Mean squares	
		Fat thickness (mm)	Final age at slaughter (days)
Year	2	84.448 **	3473.6 **
Breed group	3	115.809 **	781.9
Age of dam	2	.825	1324.4 *
Residual	145	.257	402.8

\*  $P < .05$ . \*\*  $P < .01$ .

carcass grade. Therefore, independent of breed group differences in weight, there are important differences among breed groups in carcass composition.

Analyses of variance for carcass traits of steers raised at Huntley are presented in table 30. Carcass weight was significant for both quantity traits, rib eye area and yield grade. Age of calf was not significant for the quality traits, marbling score and carcass grade, as was found with the Havre steers. This was probably due to the fact that the Huntley steers were all slaughtered at the same time. Therefore any differences in age would be a result of differences in birth dates and not a measure of time required to reach slaughter criteria, as it was at Havre. Treatment was nonsignificant for

TABLE 29. BREED GROUP MEANS AND STANDARD ERRORS FOR FAT THICKNESS AND FINAL AGE AT SLAUGHTER

Breed group	No. of animals	Fat thickness (mm)	Final age at slaughter (days)
50% Simmental-50% Hereford	46	10.95 ± .52 <sup>a</sup>	427.4 ± 3.2 <sup>a</sup>
25% Simmental-75% Hereford	36	12.80 ± .60 <sup>b</sup>	435.7 ± 3.6 <sup>a,b</sup>
Angus-Hereford	27	15.27 ± .71 <sup>c</sup>	428.5 ± 4.4 <sup>a,b</sup>
Hereford	44	13.83 ± .56 <sup>b,c</sup>	435.6 ± 3.4 <sup>b</sup>

a,b,c  
Means within column with different superscripts differ (P<.05).

TABLE 30. ANALYSES OF VARIANCE FOR CARCASS TRAITS OF HUNTLEY STEERS

Source	df	Mean squares					
		Rib eye area (cm <sup>2</sup> )	Yield grade (1 to 5)	Carcass weight (kg)	Fat thickness (mm)	Marbling score (1 to 12)	Carcass grade (1 to 14)
Treatment <sup>a</sup>	1	1.4	.068	147	.005	.616	.342
Breed group	2	51.5	1.966 **	1425	.049 **	.527	.188
Age of dam	2	27.0	.269	1274	.013	1.438	1.520
Carcass weight -lin.	1	130.5	1.814 *				
Residual	25 <sup>b</sup>	25.9	.338	683	.007	1.509	1.602

a  
Wheat vs. barley as the concentrate.

b  
Degrees of freedom for residual was 26 when carcass weight was not included as a covariate.

\*  
P < .05.

\*\*  
P < .01.

all carcass traits studied. The treatment x breed group interaction was also nonsignificant indicating that breed groups responded the same to having either barley or wheat as the major concentrate.

Breed group means (table 31) followed the same trends as the Havre steers. The 50% Simmental steers had the greatest amount of muscling and the lowest scores for carcass quality with the 25% Simmentals and straightbred Herefords being similar and opposite to the 50% Simmentals. Significant differences existed only for yield grade and fat thickness at the 12th rib.

TABLE 31. BREED GROUP MEANS AND STANDARD ERRORS FOR CARCASS TRAITS OF HUNTLEY STEERS

Breed group	No. of animals	Rib eye area (cm <sup>2</sup> )	Yield (1 to 5)	Carcass weight (kg.)	Fat thickness (mm)	Carcass grade (1 to 14) <sup>a</sup>	Marbling score (1 to 12) <sup>b</sup>
50% Simmental- 50% Hereford	12	73.7 ± 1.6	1.7 ± .2 <sup>c</sup>	307.2 ± 7.7	6.14 ± .64 <sup>c</sup>	10.7 ± .4	8.5 ± .4
25% Simmental- 75% Hereford	12	69.6 ± 1.5	2.5 ± .2 <sup>d</sup>	286.4 ± 7.7	8.04 ± .64 <sup>d</sup>	10.8 ± .4	8.8 ± .4
Hereford	8	69.8 ± 2.0	2.5 ± .2 <sup>d</sup>	289.8 ± 10.3	9.86 ± .86 <sup>d</sup>	11.0 ± .5	9.0 ± .5

<sup>a</sup>10= ave. good, 13= ave. choice.

<sup>b</sup>8= slight, 9= slight +, 10= small -.

<sup>c,d</sup>Means within column with different superscripts differ (P<.05).

Traits Associated with the Cow

Condition scores of cows were taken postcalving and at weaning. Differences in the amount of change between the two measurements should reflect variation associated with stress during the rearing period of the calf. Analyses of variance for condition score at birth, weaning and change in condition are presented in table 32. Year was highly significant for all traits. Age of dam was highly significant for both condition score at birth and weaning. The lack of a significant age of dam effect for change in condition score indicated that the amount of change was not dependent on age. However, the year x age of dam interaction for condition score at weaning and change in condition reflected differences in rankings of age groups between years.

Sex of calf was significant for change in condition. Cows raising steer calves did not have as much gain in condition as cows raising heifers. A significant year x sex of calf interaction for condition score at birth was observed. Whether this interaction was due to biological causes or that different scorers were influenced differently by the sex of the calf at the cow's side was not certain. The breed group x sex of calf interaction for condition score at weaning was

TABLE 32. ANALYSES OF VARIANCE FOR COWS' CONDITION SCORE<sup>a</sup> AT BIRTH, WEANING AND CHANGE IN CONDITION

Source	Condition score at birth (1-9)		Condition score at weaning (1-9)		Change in condition score (1-9)	
	df	Mean squares	df	Mean squares	df	Mean squares
Year (Y)	3	10.374 **	3	14.729 **	3	39.51 **
Breed group (B)	3	.100	3	3.675 **	3	2.73 +
Sex of calf (S)	1	.736	1	.736	1	4.37 *
Age of dam (A)	2	11.261 **	2	12.050 **	2	.44
Y x S	3	1.950 *				
Y x A			5	2.786 **	5	5.45 **
B x S			3	3.083 *		
Days before calving						
-lin.	1	23.442 **			1	19.86 **
Residual	429	.682	425	.815	427	1.05

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

<sup>a</sup> 1= thinnest, 9= fattest.

caused by cows rearing 50% Simmental or 50% Angus heifers having lower scores than cows rearing steers from the same breed groups. Whereas, cows rearing 25% Simmental or straightbred Hereford steers had higher scores than cows rearing heifers. The breed group x sex of calf interaction was not supported by differences in preweaning growth. Therefore, this interaction should not be interpreted as due to the rearing of the "growthier" sex of each breed group.

The covariable days before calving was initially calculated to adjust for differences in stage of gestation when precalving weights were taken. But, this was also a measure of time of calving. Days before calving was the number of days from the time precalving weights were taken until calving. Larger values meant calving occurred later in the season. The covariable days before calving was significant for both condition score at birth and change in condition. Cows calving later in the season had higher condition scores than earlier calving cows ( $b = .019 \pm .003$  units/day). Since condition score at birth was subtracted from condition score at weaning, a smaller amount of improvement in condition for later calving cows was expected ( $b = -.175 \pm .040$  units/day).

The mean change for all cows in condition score was .8

from birth to weaning. This positive change could be due to better nutrition during the summer or differences between scorers (different scorers were present at birth and weaning). Breed group was highly significant for condition score at weaning and approached significance for change in condition. Cows rearing 50% Simmental calves differed in amount of change in condition from cows rearing straightbred Hereford calves (table 33). The breed group rankings for change in condition are opposite to the rankings for preweaning growth. This would imply an inverse relationship between growth rate of the calf and condition of the cow.

Cow weights were taken precalving and at weaning. Average number of days from precalving date to calving date for all cows was 27. Weight change from precalving to weaning and weight/height ratio at weaning were also calculated. Analyses of variance for these traits are presented in table 34. The covariable days before calving was found to be nonsignificant for all traits from preliminary analyses. Year was significant for all traits. Weight changes were inconsistent between years. Average weight changes for each year were -28, -5, 15 and 27 kg for 1976, 1977, 1978 and 1979, respectively. Since different grazing leases were used for 1976 and 1977 versus

TABLE 33. BREED GROUP MEANS AND STANDARD ERRORS FOR COWS' CONDITION<sup>a</sup> AT BIRTH, WEANING AND CHANGE IN CONDITION SCORES

Breed group	No. of animals	Condition score at birth	Condition score at weaning	Change in condition
50% Simmental- 50% Hereford	107	5.3 ± .1	6.0 ± .1 <sup>b</sup>	.70 ± .12 <sup>b</sup>
25% Simmental- 75% Hereford	108	5.4 ± .1	6.3 ± .1 <sup>c</sup>	.95 ± .12 <sup>b,c</sup>
Angus-Hereford	122	5.3 ± .1	6.0 ± .1 <sup>b</sup>	.75 ± .12 <sup>b,c</sup>
Hereford	106	5.3 ± .1	6.4 ± .1 <sup>c</sup>	1.05 ± .13 <sup>c</sup>

<sup>a</sup>  
1= thinnest, 9= fattest.

<sup>b,c</sup>  
Means within column with different superscripts differ (P<.05).

TABLE 34. ANALYSES OF VARIANCE FOR COWS' PRECALVING AND WEANING WEIGHT, WEIGHT/HEIGHT AT WEANING AND WEIGHT CHANGE FROM PRECALVING TO WEANING

Source	df	Precalving weight (kg) M.S. <sup>a</sup>	df	Weaning weight (kg) M.S.	df	Weight change (kg) M.S.	df	Weight/height (kg/cm) M.S.
Year (Y)	3	17048 **	3	20175 **	3	32367 **	3	.7049 **
Breed group (B)	3	1204	3	2387	3	1911 *	3	.1366
Sex of calf	1	453	1	1095	1	56	1	.1099
Age of dam (A)	2	323199 **	2	185889 **	2	13632 **	2	7.7877 **
Y x B					6	2143 **		
Y x A			5	6662 **	5	5874 **	5	.2890 *
Residual	473	1871	468	2152	462	523	468	.1002

\*  $P < .05$ . \*\*  $P < .01$ .

<sup>a</sup> M.S. denotes Mean squares.

1978 and 1979, yearly differences may be reflecting differences in range quality. Age of dam was significant for all traits. Weights of the cows at birth and weaning were heavier with increasing age. Although, only 3- and 4-year-old cows gained weight whereas mature cows lost weight over the length of the rearing period. The year x age of dam interaction was caused by inconsistencies of weight changes between age groups and years.

Breed group was significant for weight change from precalving to weaning. Examination of breed group means (table 35) do not agree with the rankings of breed groups for change in condition (table 33). The residual correlation between weight change and condition change of  $-.20$ , suggests a small inverse relationship exists within breed groups. Why these two traits differ in direction was not apparent. The year x breed group interaction means for weight change are presented in table 36. This interaction was mainly caused by the large increase in weight gain by cows raising 50% Angus calves in 1979.

TABLE 35. BREED GROUP MEANS AND STANDARD ERRORS FOR COWS: PRECALVING AND WEANING WEIGHT, WEIGHT/HEIGHT AT WEANING AND WEIGHT CHANGE FROM PRECALVING TO WEANING

Breed group	No. of animals	Precalving weight (kg)	Weaning weight (kg)	Weight change (kg)	Weight/height (kg/cm)
50% Simmental- 50% Hereford	107	491.1 $\pm$ 4.7	488.8 $\pm$ .1	-3.5 $\pm$ 2.5 <sup>a</sup>	3.98 $\pm$ .03 <sup>a</sup>
25% Simmental- 75% Hereford	110	492.9 $\pm$ 4.6	496.8 $\pm$ 5.0	3.7 $\pm$ 2.5 <sup>b</sup>	4.03 $\pm$ .03 <sup>a, b</sup>
Angus-Hereford	127	489.5 $\pm$ 4.3	496.6 $\pm$ 4.7	7.0 $\pm$ 2.3 <sup>b</sup>	4.04 $\pm$ .03 <sup>a, b</sup>
Hereford	139	496.6 $\pm$ 4.0	498.9 $\pm$ 4.4	1.6 $\pm$ 2.2 <sup>a, b</sup>	4.06 $\pm$ .03 <sup>b</sup>

a, b. Means within column with different superscripts differ ( $P < .05$ ).

TABLE 36. MEANS AND STANDARD ERRORS FOR COWS' WEIGHT CHANGE FROM PRECALVING TO WEANING FOR THE YEAR  $\times$  BREED GROUP INTERACTION

Year	Breed group <sup>a</sup>	No. of animals	Weight change (kg)
1976	1S1H	39	-36.9 $\pm$ 4.0
1976	1S3H	39	-29.8 $\pm$ 3.9
1976	HH	39	-20.7 $\pm$ 4.1
1977	1S1H	33	-12.0 $\pm$ 4.2
1977	1S3H	37	-2.1 $\pm$ 3.9
1977	AH	36	-5.1 $\pm$ 4.0
1977	HH	37	-2.2 $\pm$ 4.0
1978	1S1H	35	13.8 $\pm$ 4.1
1978	1S3H	34	18.4 $\pm$ 4.3
1978	AH	45	14.8 $\pm$ 3.7
1978	HH	33	12.0 $\pm$ 4.4
1979	AH	46	41.0 $\pm$ 3.8
1979	HH	30	17.1 $\pm$ 4.7

<sup>a</sup>

H= Hereford, S= Simmental, A= Angus, 1S1H= 1 part Simmental and 1 part Hereford, 1S3H= 1 part Simmental and 3 parts Hereford.

Milk production of Hereford cows rearing calves of different genotypes was analyzed to determine if calf genotype affected milk production (table 37). Year was significant for the second milk production taken at an average of 132 days of lactation. Even though breed groups were not significant, cows rearing 50% Angus calves produced the most milk at the second trial (table 38). Cows rearing Angus-Hereford calves produced 61% more milk at the second trial than cows rearing straightbred Hereford calves. Some caution must be put on the importance of this, because of the small number of observations in the Angus-Hereford subclass and the distribution of calves with years. Most of the observations (56) occurred in 1976 when no Angus-Hereford calves were present.

Reynholds et al. (1978) reported cows nursing crossbred calves exceeded the milk production of cows nursing straightbred calves in most instances. Increases up to 26% were reported between the milk yield of dams suckled by crossbred and straightbred calves. Cartwright and Carpenter (1961) found that crossbred calves nursed more frequently than straightbred calves. However, Wyatt et al. (1977) working with two biological types of calves (i.e., Angus-Hereford representing a smaller early maturing breed vs. Charolais-Friesian

TABLE 37. ANALYSES OF VARIANCE FOR MILK PRODUCTION TRIALS

Source	Trial 1 (kg/day)		Trial 2 (kg/day)			
	df	Mean squares	df	Mean squares	df	Mean squares
Year	2	27.71	2	47.67 *	2	40.16 *
Breed group	3	9.89	3	20.92	3	20.74
Sex of calf	1	5.71	1	.20	1	.21
Age of dam	2	18.64	2	3.11	2	3.13
Day of lact. -lin.					1	2.09
Residual	93	12.64	92	11.51	91	11.62

\*  $P < .05$ .

TABLE 38. BREED GROUP MEANS AND STANDARD ERRORS FOR MILK PRODUCTION TRIALS

Breed group	No. of animals	Trial 1 (kg/day) 30 to 50th day of lact.	No. of animals	Trial 2 (kg/day) 130 to 150th day of lact.
50% Simmental- 50% Hereford	24	9.72 ± .90	24	4.28 ± .87 <sup>a</sup>
25% Simmental- 75% Hereford	31	9.53 ± .85	32	4.08 ± .82 <sup>a</sup>
Angus-Hereford	10	7.57 ± 1.22	10	7.19 ± 1.18 <sup>b</sup>
Hereford	37	9.00 ± .84	35	4.46 ± .82 <sup>a</sup>

a, b

Means with different superscripts differ ( $P < .05$ ).

representing a larger, later maturing breed) suggested that the potential growth rate of calves had little effect on milk intake. This is in contrast to earlier theories that the calf's capacity for milk might be a limiting factor in milk production by the dam (Cole and Johansson, 1933; Gifford, 1953; Schwulst, 1966).

If the genotype of the calf does affect milk yield of the dam, then this could partially explain the low change in condition scores for cows raising 50% Angus calves. This would seem logical since energy directed towards milk production would not be available for the cow herself.

The lack of a difference between the two Simmental groups and the straightbred Herefords suggests that suckling intensity does not differ between the two breeds or that the technique used in the present study does not allow detection of small differences. The weigh-suckle-weigh technique may have been measuring udder capacity of the cow rather than rate of milk production in response to increased calf stimulus. Another possibility was that the Hereford cows, being noted for low milk production, may not have had the ability to respond to the increased demands of growthier calves.

## GENERAL DISCUSSION

Objective of this study was to examine early growth and carcass traits of breed groups containing Simmental, Angus and Hereford breeding. Composition of the breed groups must be identified (table 39) in order to understand the contributing factors to the breed comparisons. Breed groups contained a certain proportion of the additive effects of each breed involved in their composition. Each of the breed groups, which involved crosses between breeds, obtained any heterosis from this cross. It can not be assumed that heterosis from the Simmental-Hereford cross was of the same size or direction as heterosis from the Angus-Hereford cross. Each of these crosses also obtained any complementarity, i.e., interaction of the new genotype with management or marketing systems, for the specific crosses. All breed groups were affected by maternal effects of the Hereford breed.

Since all breed groups contained a portion of the additive effects and all of the maternal effects of the Hereford breed, deviation from the straightbred Hereford group can be used to estimate the remaining portion of the equation in table 39 for each breed group. Solutions for each part of the equation are not possible. Therefore, biological explanation in terms of additive effects, heterosis and complementarity differences

between breed groups can only be theorized.

The 50% and 25% Simmental calves had longer gestation lengths than straightbred Herefords with all three breed groups having longer gestation lengths than 50% Angus calves. The longer gestation length of the 50% Simmental calves was accompanied by heavier birth weights and more calving difficulty, with the other three breed groups being similar. Incidence of calving difficulty was .3% (16) of the 529 calvings with dystocia information. Within each breed group, 50% Simmentals required the most assistance 8.9% (10) followed by 25% Simmentals, 50% Angus and Herefords requiring 2.7% (3), 1.5% (2) and .6% (1), respectively. The quadratic regression of calving difficulty on birth weight indicated that as birth weight increased above the mean (38.4 kg) the level of dystocia rose rapidly. However, significant breed group differences did exist even with birth weight included as a covariate. Thus, factors other than birth weight associated with the breed groups affected dystocia.

Percentage of calves weaned differed significantly between the 50% Simmental and 50% Angus calves. The economic importance of this was reflected in net kilograms weaned which measures both differences in growth and survival rates. On the basis of

TABLE 39. GENETIC AND ENVIRONMENTAL COMPONENTS OF BREED GROUPS

Breed <sup>a</sup> group	Additive effects from each breed		Heterosis <sup>b</sup>		Maternal <sup>c</sup> effects		Complementarity
HH	H			+	M <sub>H</sub>		
1S3H	$\frac{3}{4}H + \frac{1}{4}S$	+	$\frac{1}{2}\text{Het}_{SH}$	+	M <sub>H</sub>	+	Complementarity
1S1H	$\frac{1}{2}H + \frac{1}{2}S$	+	Het <sub>SH</sub>	+	M <sub>H</sub>	+	Complementarity
AH	$\frac{1}{2}H + \frac{1}{2}A$	+	Het <sub>AH</sub>	+	M <sub>H</sub>	+	Complementarity

<sup>a</sup> H= Hereford, S= Simmental, A= Angus, 1S3H= 1 part Simmental and 3 parts Hereford, 1S1H= 1 part Simmental and 1 part Hereford.

<sup>b</sup> Heterosis from Simmental-Hereford cross and heterosis from Hereford-Angus cross.

<sup>c</sup> Maternal effects from Hereford breed.

productivity per cow producing a calf. Angus-Hereford calves showed a distinct advantage, weaning at least 10 more kilograms of calf per calf born than any other group.

Growth traits expressed as a percentage of the straightbred Herefords growth are presented in table 40. The 50% Simmentals were heaviest at birth, exhibited the greatest preweaning growth and continued to outperform the straightbred Herefords in postweaning gain. The 25% Simmentals and 50% Angus had low birth weights, good preweaning ADG but differed dramatically in postweaning ADG.

As pointed out in table 39, the deviation from the straightbred Herefords was due to additive breed effects, heterosis and complementarity. But another factor which cannot be overlooked was the sampling process involved in selecting the sires. It was calculated earlier (experimental design) that progeny from Hereford and Angus sires when mated to a random group of cows from their respective breed, would be expected to have average ratios of 102 and 104, respectively, for adjusted 205-day weight and 104 and 105 for adjusted yearling weight if compared to progeny from all bulls from all herds sampled. Whereas, the Simmental sires were more representative of the Simmental breed and the 50% Simmental-50% Hereford sires were representative of an average or slightly

TABLE 40. GROWTH TRAITS OF BREED GROUPS EXPRESSED AS A PERCENTAGE OF THE STRAIGHTBRED HEREFORD'S GROWTH

Breed group	Birth weight	Prewaning ADG	180-day wt.	Postweaning ADG
50% Simmental- 50% Hereford	109	109	109	105
25% Simmental- 75% Hereford	100	105	104	97
Angus-Hereford	98	106	104	106
Hereford	100	100	100	100

below average of sons of the Simmental sires.

In order to adjust for the differences in selection intensities of the groups of bulls sampled, the Angus-Hereford and straightbred Hereford ratios in table 40 were divided by the expected progeny ratios of the Angus and Hereford sires, respectively. This was done using progeny ratios for adjusted 205-day weight to correct the 180-day weight ratios. Although no actual estimates were available for selection differences in postweaning ADG, the yearling weight ratios gave an approximate estimate of how much the bulls selected deviated from breed average in postweaning ADG and thus were used to correct postweaning ADG ratios. After the division, all breed group ratios were multiplied by the inverse of the straightbred Hereford ratio to again express all breed group means as a percentage of the straightbred Herefords.

These adjustments for 180-day weight resulted in adjusting the 50% and 25% Simmental ratios up by 2% (table 41). The 50% Angus ratio was in effect adjusted down 2% since their expected progeny ratio was higher than the straightbred Herefords. The postweaning ADG adjustments resulted in an increase of 4% for both 50% and 25% Simmentals and a 1% decrease for the 50% Angus group. With these adjustments, the 25% Simmental group was

TABLE 41. GROWTH TRAITS OF BREED GROUPS EXPRESSED AS A PERCENTAGE OF THE STRAIGHTBRED HEREFORD'S GROWTH AFTER ADJUSTING FOR DIFFERENCES IN SELECTION INTENSITIES

Breed group	Birth weight	Preweaning ADG	180-day wt.	Postweaning ADG
50% Simmental- 50% Hereford	109	109	111	109
25% Simmental- 75% Hereford	100	105	106	101
Angus-Hereford	98	106	102	105
Hereford	100	100	100	100

slightly above (101) the straightbred Hereford group for postweaning ADG. This was more in agreement with the theoretical expectation of the 25% Simmental mean lying between the 50% Simmental and straightbred Hereford means. The adjustment to postweaning ADG was only approximate and interpretations must be made with caution.

The 2% adjusted advantage of the Angus-Hereford calves over straightbred Hereford calves for 180-day weight could be mostly due to heterosis. Results from the literature point to little difference in additive gene effects between the Angus and Hereford breeds for 205-day weight. Whereas, a review by Warwick (1968) of 14 studies involving crossbreeding between British breeds indicated a weighted heterosis average of 4.6%. For the Angus and Hereford cross, Mason (1966) reported on unweighted heterosis average from 11 studies of 3.6%.

Estimates of heterosis have not been as numerous for Continental breeds due to the small number of purebred cows until recent years. The results of Klosterman et al. (1968), Pahnish et al. (1969), Sagebiel et al. (1974), Peacock et al. (1978) and Allenda et al. (1980) showed heterosis estimates obtained from crossing Charolais with British breeds of the same magnitude as British crosses. It is therefore expected that

other Continental breeds will also show the same magnitude of heterosis when crossed with British breeds. If this was true for the present study, then almost two-thirds of the advantage at weaning for the 50% and 25% Simmental calves was due to a greater additive gene effect of the Simmental breed.

There were important differences among breed groups in carcass composition, independent of variation due to carcass weight or age of calf. The carcass traits reveal an antagonism between quantity and quality. The rankings of breed groups for indicators of quantity, i.e., yield grade and rib eye area were 50% Simmental, 25% Simmental, straightbred Hereford and 50% Angus. The rankings of breed groups for indicators of carcass quality, i.e., marbling score and carcass grade were exactly opposite. Identification of breed groups which combine levels of carcass quantity and quality at different amounts will allow matching of optimum weights and grades desired by different markets. This will allow maximum complementarity among breeds in best arriving at a desired carcass.

Comparison of breed groups for beef production is not complete until relationships are studied and all phases of the industry are evaluated. One attempt in the present study was how the genotype of the calf affected the performance of the

cow. Changes in condition scores of the cows suggested that stress of rearing a calf was dependent on the genotype of the calf. The milk production trials gave some support that this was through differential amounts of milk provided. This would seem logical since energy directed towards milk production would not be available for the cow herself. However, weight changes of the cows were not supportive of this hypothesis.

SUMMARY

Performance of 543 (birth) to 153 (carcass) calves raised on 3-year-old and older Hereford dams was analyzed using least-squares procedures. Analyses of variance generally included year, breed group, sex, age of dam, appropriate two-factor interactions and appropriate covariates. Data were collected during the years 1976 through 1979 at the Northern Agricultural Research Center near Havre. The objective of the study was to examine early growth and carcass traits of beef cattle containing Simmental, Angus and Hereford breeding. Breed groups studied were 50% Simmental-50% Hereford (1S1H), 25% Simmental-75% Hereford (1S3H), Angus-Hereford (AH) and straightbred Herefords (HH). The 1S1H group had the longest gestation length, heaviest birth weight, most calving difficulty, lowest level of calves weaned, greatest growth rate, least fat, highest yield and lowest degree of marbling. Conversely, the AH group differed in all traits except postweaning ADG, where it was similar. The 1S3H and HH groups were similar and intermediate for most traits differing only by the 1S3H group having a longer gestation length and higher preweaning ADG. Least-squares means for the growth traits (kg) birth weight, preweaning and postweaning ADG were 41.4, .884 and 1.17 for 1S1H; 37.9, .856 and

1.08 for 1S3H; 37.2, .858 and 1.18 for AH; 37.9, .813 and 1.12 for HH.

The results presented here, represent variation among only several of the many possible breed combinations. However, these results coupled with the results of research being conducted around the world, will enable future recommendations to be made concerning many biological types and environments. This knowledge will allow beef producers to discriminately utilize variability among breeds to most efficiently produce highly palatable and nutritious beef.

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APPENDIX

APPENDIX TABLE 1. MEANS AND STANDARD ERRORS FOR AGE OF DAM CLASSIFICATIONS

Traits	No. of animals	3-year-old dams	No. of animals	4-year-old dams	No. of animals	Mature dams
Birth wt. (kg)	76	37.2 $\pm$ .5	114	38.5 $\pm$ .4	353	40.1 $\pm$ .2
Gestation length (days)	75	284.8 $\pm$ .7	114	285.6 $\pm$ .6	352	286.4 $\pm$ .3
Calving difficulty score	71	1.18 $\pm$ .04	109	1.01 $\pm$ .03	346	1.03 $\pm$ .02
Early survival (0=dead, 1=alive)	76	.98 $\pm$ .01	114	.98 $\pm$ .01	353	.99 $\pm$ .01
Late survival (0=dead, 1=alive)	74	.97 $\pm$ .02	112	.99 $\pm$ .01	349	.99 $\pm$ .01
Percentage weaned (%)	73	.94 $\pm$ .02	107	.97 $\pm$ .02	325	.97 $\pm$ .01
Prebreeding weight (kg)	70	78.4 $\pm$ 1.2	102	83.5 $\pm$ 1.0	318	85.9 $\pm$ .6

APPENDIX TABLE 1. (CONTINUED)

Traits	No. of animals	3-year-old dams	No. of animals	4-year-old dams	No. of animals	Mature dams
ADG (birth to weaning) (kg/day)	69	.814 <sub>±</sub> .013	103	.860 <sub>±</sub> .012	316	.884 <sub>±</sub> .006
180-day weight(kg)	69	183.5 <sub>±</sub> 2.5	103	193.7 <sub>±</sub> 2.2	316	199.2 <sub>±</sub> 1.2
Condition score	69	5.7 <sub>±</sub> .1	103	6.2 <sub>±</sub> .1	316	6.3 <sub>±</sub> .1
Wither height(cm)	69	97.6 <sub>±</sub> .4	101	99.1 <sub>±</sub> .4	315	99.5 <sub>±</sub> .2
Weight/height (kg/cm)	69	1.90 <sub>±</sub> .02	101	1.98 <sub>±</sub> .02	315	2.02 <sub>±</sub> .01
Postweaning ADG (kg/day)	24	1.12 <sub>±</sub> .03	29	1.13 <sub>±</sub> .03	99	1.15 <sub>±</sub> .02
Carcass weight(kg)	25	246.1 <sub>±</sub> 3.2	29	245.3 <sub>±</sub> 3.2	99	250.1 <sub>±</sub> 1.6
Days to slaughter (days)	25	438.7 <sub>±</sub> 4.2	29	429.5 <sub>±</sub> 4.2	99	427.1 <sub>±</sub> 2.1

APPENDIX TABLE 1. (CONTINUED)

Traits	No. of animals	3-year-old dams	No. of animals	4-year-old dams	No. of animals	Mature dams
Fat thickness (mm)	25	13.40 <sub>+</sub> .68	29	13.04 <sub>+</sub> .69	99	13.19 <sub>+</sub> .36
Yield grade	25	2.4 <sub>+</sub> .1	29	2.4 <sub>+</sub> .1	99	2.5 <sub>+</sub> .1
Carcass grade	25	18.4 <sub>+</sub> .2	29	18.5 <sub>+</sub> .2	99	18.6 <sub>+</sub> .1
Marbling score	25	5.8 <sub>+</sub> .4	29	6.0 <sub>+</sub> .4	99	6.2 <sub>+</sub> .2
Dressing %	25	55.1 <sub>+</sub> .3	29	54.8 <sub>+</sub> .3	99	55.0 <sub>+</sub> .2
Rib eye area (cm <sup>2</sup> )	25	73.5 <sub>+</sub> 1.2	29	71.9 <sub>+</sub> 1.2	99	71.7 <sub>+</sub> .6
Rib eye length(mm)	25	142.9 <sub>+</sub> 1.3	29	140.2 <sub>+</sub> 1.4	99	142.7 <sub>+</sub> .7
Rib eye width (mm)	25	60.19 <sub>+</sub> .80	29	59.40 <sub>+</sub> .80	99	58.61 <sub>+</sub> .40

APPENDIX TABLE 2. YEARLY MEANS AND STANDARD ERRORS

Traits	No. of animals	1976	No. of animals	1977	No. of animals	1978	No. of animals	1979
Birth weight (kg) --	121	39.3 ± .4	154	39.4 ± .4	156	37.8 ± .4	112	37.8 ± .5
Gestation length (days) -----	120	266.2 ± .6	153	285.8 ± .5	156	287.0 ± .5	112	285.6 ± .7
Calving difficulty score -----	118	1.08 ± .03	144	1.07 ± .02	153	1.07 ± .02	111	1.07 ± .03
Early survival (0=dead, 1=alive) --	121	.96 ± .01	154	.98 ± .01	156	.99 ± .01	112	.99 ± .01
Late survival (0=dead, 1=alive) --	119	1.01 ± .01	151	.97 ± .01	154	.97 ± .01	111	.96 ± .02
Percentage weaned (%) -----	120	.99 ± .02	153	.95 ± .01	153	.96 ± .02	79	.94 ± .02
Prebreeding wt. (kg) -----	118	88.5 ± 1.0	148	77.6 ± .8	148	79.8 ± .9	76	84.6 ± 1.3
ADG (birth to weaning) (kg/day) --	118	.848 ± .013	146	.869 ± .010	148	.814 ± .011	76	.881 ± .016
180-day weight (kg) -----	118	192.0 ± 2.4	146	196.0 ± 1.9	148	184.4 ± 2.1	76	196.2 ± 3.1
Condition score --	118	6.5 ± .1	146	6.5 ± .1	148	5.5 ± .1	76	5.7 ± .1
Wither height (cm) --	116	97.3 ± .4	146	98.3 ± .3	147	98.7 ± .4	76	100.5 ± .5
Weight/height (kg/cm) -----	116	2.01 ± .02	146	2.02 ± .02	147	1.89 ± .02	76	1.95 ± .03
Postweaning ADG (kg/day) -----	28	1.20 ± .04	69	1.12 ± .02	55	1.09 ± .03		
Carcass weight(kg) --	29	251.7 ± 3.3	69	253.0 ± 2.0	55	236.8 ± 2.4		
Days to slaughter (days) -----	29	420.3 ± 4.4	69	435.1 ± 2.6	55	439.9 ± 3.1		
Fat thickness (mm) --	29	15.10 ± .71	69	12.20 ± .42	55	12.33 ± .50		
Yield grade -----	29	2.6 ± .1	69	2.0 ± .1	55	2.7 ± .1		
Carcass grade -----	29	18.9 ± .2	69	18.5 ± .1	55	18.1 ± .1		
Marbling score -----	29	6.8 ± .4	69	5.9 ± .2	55	5.4 ± .3		
Dressing % -----	29	55.3 ± .3	69	55.2 ± .2	55	54.5 ± .2		
Rib eye area (cm <sup>2</sup> ) --	29	70.4 ± 1.3	69	74.4 ± .7	55	72.3 ± 1.0		
Rib eye length(mm) --	29	138.7 ± 1.4	69	143.0 ± .8	55	144.2 ± 1.1		
Rib eye width (mm) --	29	59.54 ± .83	69	60.57 ± .5	55	58.09 ± .63		

APPENDIX TABLE 3. SEX OF CALF MEANS AND STANDARD ERRORS

Traits	No. of animals	steers	No. of animals	heifers
Birth weight (kg)	300	40.0 $\pm$ .3	243	37.2 $\pm$ .3
Gestation length (days)	298	286.7 $\pm$ .4	243	284.5 $\pm$ .4
Calving difficulty score	291	1.13 $\pm$ .02	235	1.02 $\pm$ .02
Early survival (0=dead, 1=alive)	300	.98 $\pm$ .01	243	.99 $\pm$ .01
Late survival (0=dead, 1=alive)	294	.98 $\pm$ .01	241	.98 $\pm$ .01
Percentage weaned(%)	270	.95 $\pm$ .01	235	.97 $\pm$ .01
Prebreeding wt. (kg)	259	85.1 $\pm$ .7	231	80.2 $\pm$ .7
ADG (birth to weaning) (kg/day)	257	.871 $\pm$ .008	231	.834 $\pm$ .008
180-day weight (kg)	257	196.9 $\pm$ 1.5	231	187.4 $\pm$ 1.6
Condition score	257	6.2 $\pm$ .1	231	5.9 $\pm$ .1
Wither height (cm)	255	99.1 $\pm$ .3	230	98.3 $\pm$ .3
Weight/height(kg/cm)	255	2.00 $\pm$ .01	230	1.93 $\pm$ .02

APPENDIX TABLE 4. INCIDENCE AND TYPE OF DYSTOCIA AMONG BREED GROUPS

Calving difficulty scores	Breed groups <sup>a</sup>			
	1S1H	1S3H	AH	HH
5	4	2	5	3
4	0	0	0	0
3	8	1	1	0
2	2	2	1	1
1	98	106	129	163

<sup>a</sup>S= Simmental, H= Hereford, 1S1H= 1 part Simmental and 1 part Hereford and 1S3H= 1part Simmental and 3 parts Hereford.

APPENDIX TABLE 5. CHARACTERISTICS OF CALVES THAT DIED BETWEEN 24 HOURS AFTER BIRTH TO WEANING

Breed group <sup>a</sup>	Year	Calving difficulty score	Age of dam	Sex of calf
1S1H	1976	3	3	steer
1S1H	1976	3	3	heifer
1S3H	1977	5	9	steer
HH	1977	1	7	heifer
HH	1977	1	4	steer
1S3H	1978	3	5	steer
HH	1978	1	5	steer
AH	1979	2	4	steer

<sup>a</sup>S= Simmental, H= Hereford, 1S1H= 1 part Simmental and 1 part Hereford and 1S3H= 1 part Simmental and 3 parts Hereford.

APPENDIX TABLE 6. RESIDUAL CORRELATIONS AMONG BIRTH TRAITS

Traits	Traits		
	2	3	4
Gestation length (1)	.23	.09	NA <sup>a</sup>
Birth weight (2)		.09	.03
Calving difficulty (3)			-.37
Early survival (4)			

<sup>a</sup>NA= not available.

APPENDIX TABLE 7. RESIDUAL CORRELATIONS AMONG PREWEANING TRAITS

Traits	Traits					
	2	3	4	5	6	7
Birth weight (1)	.46	.14	.35	.15	.33	.28
Prebreeding weight (2)		.71	.77	.57	.56	.73
ADG (birth to weaning) (3)			.98	.73	.61	.94
180-day weight (4)				.73	.65	.95
Condition score (5)					.36	.74
Wither height (6)						.39
Weight/height (7)						

APPENDIX TABLE 8. RESIDUAL CORRELATIONS AMONG CARCASS TRAITS AT HAVRE

Traits	Traits									
	2	3	4	5	6	7	8	9	10	
Carcass weight (1)	.03	.03	.06	.37	.50	.41	.28	.14	-.01	
Marbling score (2)		.85	.15	.04	.03	-.01	.11	.15	.22	
Carcass grade (3)			.07	.05	.08	-.01	.18	.13	.23	
Yield grade (4)				.07	-.60	-.48	-.51	.78	.04	
Dressing % (5)					.29	.20	.17	.17	.21	
Rib eye area (6)						.73	.80	-.14	0	
Rib eye length (7)							.32	-.16	0	
Rib eye width (8)								-.11	-.02	
Fat thickness (9)									.01	
Days to slaughter (10)										



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