Sire by region interaction for production traits in beef cattle
by Thomas Robert Nunn

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Animal Science
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Abstract:
Data from 38,261 field records obtained from the American Simmental Association were used to evaluate the importance of sire x region interactions in beef cattle for birth weight, weaning weight, yearling weight, gestation length and calving ease. Data were analyzed by least squares procedures by a model containing sire, region and sire x region interaction effects. Trait ratios were used in all analyses. Only progeny born and weaned in the same herd were included. The United States was divided into nine regions with one region deleted due to small numbers. Montana was further divided into three sub-regions to study the interaction within one state for birth weight and weaning weight. Birth weight and weaning weight were analyzed using separate analyses of records from all eight regions, four regions containing 85% of the records, two regions (Texas and Oklahoma vs. Montana) and the three regions of Montana. Records from five regions were analyzed for yearling weight and from three regions for gestation length and calving ease. The number of records for these latter three traits was small.

The progeny of 10-13 sires were used in each analysis. The region effect was not significant for any trait. The sire effect was significant for all analyses except weaning weight within Montana, yearling weight and calving ease. The sire x region interaction effect was significant for all analyses of weaning weight (P<.01) except Montana and approached significance (P=.07) for birth weight within Montana. Genetic correlations were calculated from the sire and sire x region interaction variance components for each analysis to assess the average change in sire performance among regions. Correlations were not defined for the within Montana weaning weight or calving ease. Correlations of unity were obtained for all analyses of birth weight except Montana and for gestation length indicating no change in the ranking of sires. For birth weight within Montana and yearling weight, correlations of 0.21 and 0.25 were obtained, respectively, suggesting some changes in the ranking of sires. Correlations of 0.47 to 0.54 suggested that changes in the ranking of sires occurred for weaning weight. This was confirmed from the least squares means for the sire x region subclasses. The sine x region variance component was less than 27° of the total variance for any given analysis of weaning weight. Although this was a small percent, it could be important biologically. The least squares means for the sire x region subclasses indicated that in many cases a given sire ranked above average in one region but below average in other regions. This indicated that errors could be made in applying the results of progeny tests in one region to progeny performance and selection in a different region. The need for evaluating sires in all regions and on a within region basis was suggested.

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A thesis submitted to the Graduate Faculty in partial
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Approved:

[signature: R. A. Blackwell]

Head, Major Department

[signature: O. D. Knox]

Chairman, Examining Committee

[signature: Henry L. Parsons]

Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

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ABSTRACT

Data from 38,261 field records obtained from the American Simmental Association were used to evaluate the importance of sire x region inter-actions in beef cattle for birth weight, weaning weight, yearling weight, gestation length and calving ease. Data were analyzed by least squares procedures by a model containing sire, region and sire x region inter-action effects. Trait ratios were used in all analyses. Only progeny born and weaned in the same herd were included. The United States was divided into nine regions with one region deleted due to small numbers. Montana was further divided into three sub-regions to study the inter-action within one state for birth weight and weaning weight. Birth weight and weaning weight were analyzed using separate analyses of records from all eight regions, four regions containing 85% of the records, two regions (Texas and Oklahoma vs. Montana) and the three regions of Montana. Records from five regions were analyzed for year-ling weight and from three regions for gestation length and calving ease. The number of records for these latter three traits was small. The progeny of 10-13 sires were used in each analysis. The region effect was not significant for any trait. The sire effect was signifi-cant for all analyses except weaning weight within Montana, yearling weight and calving ease. The sire x region interaction effect was sig-nificant for all analyses of weaning weight (P<.01) except Montana and approached significance (P=.07) for birth weight within Montana. Genetic correlations were calculated from the sire and sire x region inter-action variance components for each analysis to assess the average change in sire performance among regions. Correlations were not defined for the within Montana weaning weight or calving ease. Correlations of unity were obtained for all analyses of birth weight except Montana and for gestation length indicating no change in the ranking of sires. For birth weight within Montana and yearling weight, correlations of 0.21 and 0.25 were obtained, respectively, suggesting some changes in the ranking of sires. Correlations of 0.47 to 0.54 suggested that changes in the ranking of sires occurred for weaning weight. This was confirmed from the least squares means for the sire x region subclasses. The sire x region variance component was less than 2% of the total variance for any given analysis of weaning weight. Although this was a small percent, it could be important biologically. The least squares means for the sire x region subclasses indicated that in many cases a given sire ranked above average in one region but below average in other regions. This indicated that errors could be made in applying the results of progeny tests in one region to progeny performance and selection in a different region. The need for evaluating sires in all regions and on a within region basis was suggested.

INTRODUCTION

A genotype-environment interaction may be defined as the differential response of genotypes over environments. The effect of genotype on phenotype is not the same in two different environments.

Beef cattle are raised over a wide range of climatic conditions and in various types of production programs. There is also a great amount of movement of breeding cattle among environments. The existence of genotype-environment interactions may mean that the best performing genotype in one environment is not the best in a different environment. If these interactions are important sources of variation, the increased use of sires by artificial insemination over a wide range of geographical areas should cause concern in the selection of sires. Studies with beef cattle are not in agreement as to the importance of genotype-environment interactions.

The purpose of the present study was to evaluate the importance of sire x region interactions in beef cattle and to determine if significant interactions were due to changes in the ranking of sires among regions. The traits studied included calving ease, gestation length, birth weight, weaning weight and yearling weight.

LITERATURE REVIEW

General

Hammond (1947) suggested that selection is most effective if carried out under environmental conditions which favor the fullest expression of the trait desired. Once the trait is selected to the desired level, the animals could be used in other environments, if other characters required by the new environment are present in the animals.

Lush (1945) and Falconer (1952) have recommended that selection should occur in the same environment in which the selected animals and their offspring are expected to perform. Falconer and Latyszewski (1952) pointed out that if genotype-environment interactions are important, Hammond's thesis may not be correct. They suggested that a great increase in heritability would be the only reason for favoring selection in an environment other than the one in which the improved animal is expected to live.

Robertson, O'Connor and Edwards (1960) have asked several important questions regarding the importance of genotype-environment interactions: "Does the environmnetal level affect the ability to pick the animals of superior genetic merit in that environment? In technical terms, is the heritability different in the different environments? Is the ranking of animals on the basis of genetic merit the same in all environments? In other words, what is the correlation between breeding value in the different environments, or rather less helpfully, is there an interaction between genotype and environment?"

The idea of expressing genotype-environment interaction as a genetic correlation if only two environments are considered was developed by Falconer (1952). Performance of a trait in the two environments is regarded as two different traits which are genetically correlated. This helps to decide if selection should be made in the environment in which the animals are expected to live or in some other environment in which the desired trait is more fully expressed.

Robertson (1959) expanded on this idea and presented formulae for estimating the genetic correlation of the performance of the same genotype in two or more environments from the mean squares in a two-way factorial analysis of variance. He stated that an interaction may be due to a difference in the between genotype variance or in the true ranking of genotypes. A genetic correlation of unity indicates no interaction. Robertson further stated that estimation of the genetic correlation gives a practical rather than statistical indication of the significance of the results. He suggested that an estimate of genetic correlation equal to about 0.8 would be of biological importance.

A similar method of estimating the genetic correlation from the genotype and genotype by environment interaction components of variance was presented by Dickerson (1962). He suggested that one of the most probable kinds of genotype-environment interaction is a change in emphasis between traits as the environment changes.

Falconer and Latyszewski (1952) selected two strains of mice for

six-week body weight, one under restricted and one under full diet
conditions. When environments were exchanged for the two strains,
the one selected under restricted feed was superior to the full diet
strain when on limited feed. Under full feeding, the full diet strain
was superior but the restricted diet strain followed closely and was
better than the unselected level for full diet.

Falconer (1960) reported on a similar experiment using mice, in
which selection for high and low body weights was carried out on both
normal and restricted diets. An exchange of diets was made between the
two high lines and the two low lines. The best overall performance for
high growth rate was produced by selection on the restricted diet and
for reduced growth, on the normal diet. The results indicated that
selection should be made in the environment in which the animals are
destined to live.

In a similar study, Fowler and Ensminger (1960) selected swine
for rate of gain on high (H) and low (L) planes of nutrition (full vs.
restricted feed). After six generations of selection, half of each
line was transferred to the other treatment. This gave four groups,
HH, HL, LH and LL. Results of selection showed the LH group to be
more efficient in feed conversion and to gain faster than the HH pigs.
The HL group gained slower and was less efficient in feed utilization
than the LL group. The importance of interaction was shown from the
pooled estimate of r_g which was 0.70 for rate of gain between the two
treatments. The authors concluded that two types of genotypes were

produced in this study; on the low plane of nutrition, a genotype for efficient feed utilization and on the high plane, a genotype for large appetite and food consumption.

Results from the three previously cited studies supported Lush's (1945) and Falconer's (1952) conclusions that selection should be carried out in the environment in which the animals are to perform.

Classification of Interactions

Haldane (1946) was the first to classify different types of interaction. With two environments and two genotypes, he outlined six different types of interaction. He further showed that with m genotypes and n environments, there would be $\frac{(mn)!}{m! \, n!}$ possible kinds of interaction.

McBride (1958) proposed a classification of genotypes into "inter" and "intra" populations and environments into "macro" and "micro", with four different types of interaction resulting. "Macro-environments" would include different climates or management practices; whereas, "micro-environments" refer to minor environmental differences such as sub-clinical infections. Population differences would be those between breeds, lines or strains. McBride suggested that the interactions likely to be of importance in large animal breeding are those involving, "inter-population genotypes" and "macro-environments" and those between "intra-population genotypes" and "macro-environments".

A similar classification was made by Dunlop (1962) in describing differences in genotypes and environments as "large" or "small".

Small genetic differences are those occurring among individuals of a
herd or related herds of a breed or strain; whereas, large differences
refer to those between breeds, strains or species. Similarly, he
defined small environmental differences as those between individuals
in the same general environment and large differences as those between
regions or widely different management practices. From this classifi-
cation, the important interactions in large animal breeding would be
small genetic x large environmental differences (i.e., selection in
one environment for use in another) and large genetic x large environ-
ment differences (i.e., selecting a breed for a certain area).

Pani and Lasley (1972) outlined a slightly different and perhaps
more practical classification based on the ranking of genotypes from
one environment to another and the statistical significance of the
interaction effects. This classification is outlined in figure 1. A
significant interaction may be caused by a change in the ranking of
genotypes (type 4) or a difference in the magnitude of genotypes
(type 3). A change in the ranking of genotypes is important where
selection is carried out in one environment for use in another or
different environment. Differences in the magnitude of interaction
can influence heritability and affect the effectiveness of selection
for performance in other environments.

Hull and Gowe (1962) studied the magnitude of genotype-environ-
ment interaction using two strains of poultry at three widespread
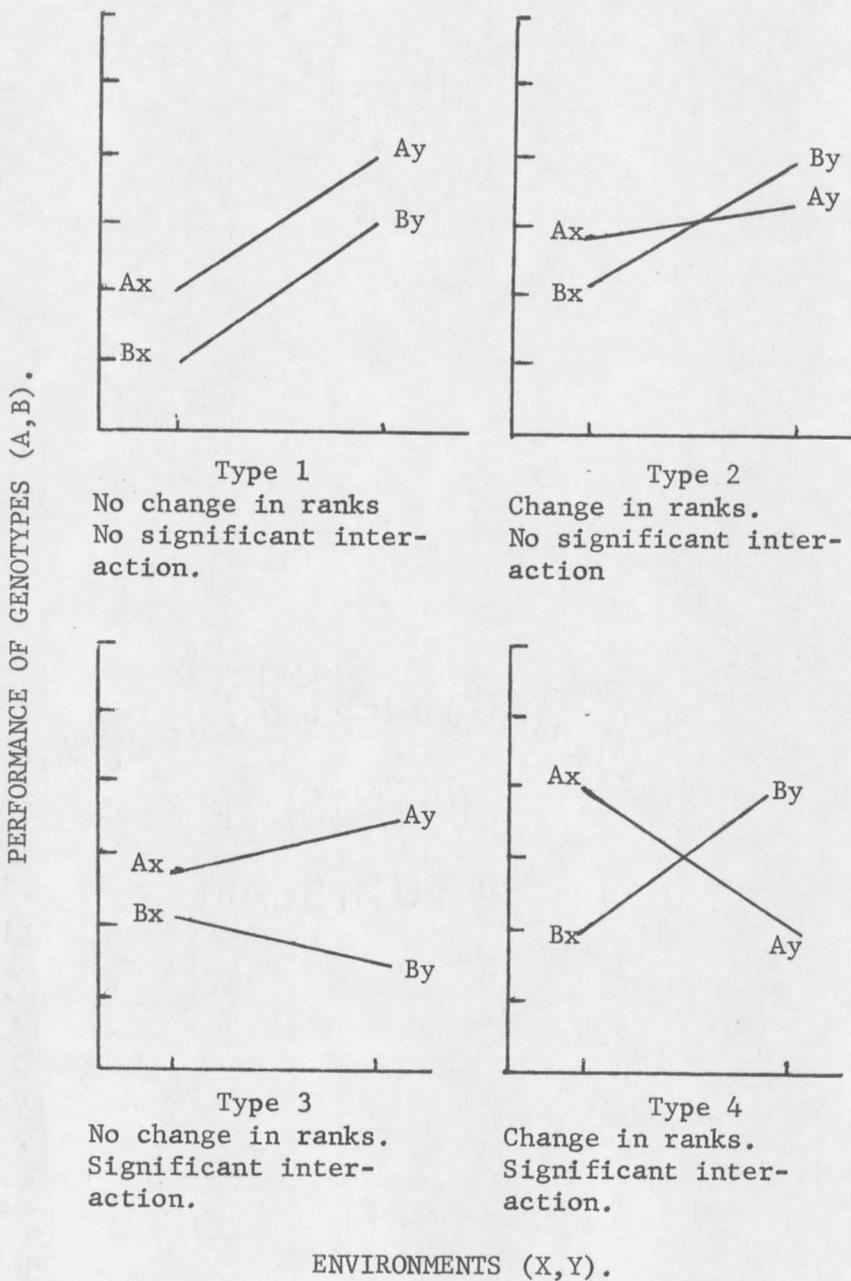
Figure 1. Four different types of genetic x environmental
interactions. (From Pani and Lasley, 1972).

locations in three different years and under two rearing programs at each location. From the results, they outlined the conditions under which interaction is likely to be important in a breeding program. Variation due to environmental treatments must be large in comparison to the non-genetic variation within the environments and the genetic variance between the genotypes must be large when compared to the total phenotypic variance within environment. Thus, large and important interactions were found in this study only when the environmental effects were large and the genetic differences were wide. However, it should be noted that this conclusion was based on the performance of only two strains.

Dairy Cattle

Generally, dairy cattle management practices could be expected to be somewhat more uniform than those of beef cattle. However, the importance of genotype-environment interactions may be similar for both classes of livestock, in that selection and testing of bulls may be carried out under good management conditions for use over herds of lower management or in other locations. For these reasons, several representative papers are reviewed on dairy cattle, most of which center on sire x herd interactions. Also, several papers on growth traits which may be more directly applicable to beef cattle interactions are reviewed.

Legates, Verlinden and Kendrick (1956) analyzed records of 24,754 daughters of Guernsey and Holstein sires used in artificial

insemination units throughout the United States. Results of this study showed that the interaction component accounted for essentially none of the total variance for milk yield, fat yield and butterfat test on a within-state basis. Specific sire x herd interactions were not of major importance in these data. Other studies by Wadell and McGilliard (1959), Van Vleck, Wadell and Henderson (1961), Burdick and McGilliard (1963) and McDaniel and Corley (1967) determined that the interaction component was a small or negligible percent of total variance.

Van Vleck (1963) calculated genetic correlations between progeny groups in four management levels for milk and fat yield. All correlations were high, ranging from 0.93 to 1.0. Similar experiments by Mason and Robertson (1956), Roberston et al. (1960), McDaniel and Corley (1967) and Burnside and Rennie (1968) resulted in correlations very near unity for sire evaluations at different herdmate levels, indicating that sires will rank essentially the same under different herd levels. However, Brumby (1961) tested identical twins in two herd levels and obtained a genetic correlation of 0.11, indicating that genotype-environment interaction was an appreciable source of variance.

Van Vleck (1963) found that genetic variance was higher for high production level herds and the fraction of total variance due to genetic variance was lower in the low production herds than in the higher herds. An earlier study by Mason and Robertson (1956) produced a similar result with significantly higher heritability estimates in high

producing herds. Heritability estimates were 0.05, 0.12 and 0.22 for low, medium and high level herds.

Studies by Robertson et al. (1960), Legates (1962), McDaniel and Corley (1967), Lytton and Legates (1966) and Burnside and Rennie (1968) concluded that the variance between progeny groups was higher at high levels of production. However, not all have found heritability to be higher at the high levels of production, due to the within-sire variance increasing at the higher levels also. The studies of Robertson et al. (1960), Legates (1962) and Burnside and Rennie (1968) found little or no difference in heritability estimates at different herd levels.

Records of 10,548 artificially sired progeny of 48 Holstein sires used in the northern and southern regions of the United States were examined by Lytton and Legates (1966) to study sire x region interactions for milk yield, fat yield, and fat test. Genetic correlations between the breeding values of the sires in the two regions approached unity, indicating that the sires ranked essentially the same. The sire x region interaction variance was close to zero. The results indicated that the ranking order of sires was not likely to be influenced by regional differences.

Mao and Burnside (1969) used artifically sired progeny to study the interaction of sire with various herd management factors. They found no interaction of sire with milk price, use of artificial

breeding, source of water on pasture, forage feeding methods in winter and summer, exercise in winter, herd size, grain feeding in winter and housing system. However, a significant interaction was found between sire proof and level of grain feeding in summer.

In an earlier study using Michigan DHIA records, Burdick and McGilliard (1963) found no interaction of importance between sires and herd environments classified by production level, days dry, location, calving interval, or type of housing. The ranking of sires was essentially the same in all environments studied. Wiggans and Van Vleck (1970) observed no significant sire by housing system interaction in a study comparing stanchion and free stall housing for Holstein cows.

From the results of these studies, it would appear that interactions involving levels of herd production, type of housing and other differences in herd environments are unimportant for dairy cattle for milk and butterfat production.

Bonnier, Hansson and Skjervold (1948) studied the effect of two levels of nutrition on monzygous twins and reported significant interactions for weight gain from 1 to 27 months of age. However, the twin set x feeding level interaction was not significant for increase in height at the shoulders.

Hansson, Brannang and Claesson (1953) reported no significant interaction for growth from 1 to 25 months of age with identical twins on four planes of nutrition.

Two methods of rearing male calves from two days of age to a market weight of 130 kg were contrasted by Burnside, MacLeod and Grieve (1969). They found no evidence of significant pair x ration interaction for growth in body weight, heart girth and height at shoulder.

Freeman (1969) fed identical and fraternal Holstein twins on high and low grain rations and found pair x ration interactions to be small or negligible for growth to 40 months of age.

Sheep

Pani and Lasley (1972) suggested that due to regional differences in housing, feeding, management, climate and altitude, genotype-environment interactions may be more important in sheep than other farm animals such as dairy cattle or poultry. They also suggested that the environmental conditions to which sheep and beef cattle are exposed may be fairly similar. A number of studies concerning sheep are reviewed for these reasons.

Carter et al. (1971b) compared the performance of two breed crosses of ewes (North Country Cheviot x Leicester and Hampshire x Hampshire-Rambouillet) at two locations, Ontario, Canada and Virginia, U.S.A. Significant ewe breed x location interactions were found for birth weight (P<.05) and 120 day weight (P=.07) of the lambs produced. However, these interaction effects were small and of no great biological importance. The interaction was not significant for preweaning ADG.

An earlier paper by Carter et al. (1971a) reported on ewe productivity for the same experiment. Important and significant interactions of location x breed cross were found for percentage of ewes lambing, weight of lamb weaned per ewe mated, and average lambing date. The authors concluded that local adaptation of ewe breeds was important for total production.

Morley (1956) measured the weight gain of Australian Merino half sibs on high and low planes of nutrition from 3 to 17 months of age and found no evidence of genotype-environment interaction for weight at 6 months of age. However, significant interactions were observed for weight at 12 and 17 months of age. Heritability estimates for these traits did not vary with plane of nutrition.

Dunlop (1963) studying five strains of Australian Merinos at three different locations, found strain x location interactions to account for only a very small fraction of the total variance for birth weight and weaning weight.

King and Young (1955) wintered Cheviot, Blackface and Wiltshire lambs under two widely different levels of temperature and two planes of nutrition. They reported no significant breed x environment interaction for change in body weight but did find significant interaction for measurement of cannon, tibia and pelvis.

King, Watson and Young (1959) compared Blackfaces and their crosses (x Lincoln, Wiltshire and Leicester rams) and Welsh and their

crosses (x Suffolk and Wiltshire rams) wintered as lambs on four planes of nutrition. There was a similar response of all the different geno-types to the four nutritional environments for growth and carcass traits, with no evidence of breed cross x plane of nutrition interaction.

Osman and Bradford (1965) used whiteface Targhee type sheep at two locations in California to study genotype-environment interaction and the effects of environment on phenotypic and genetic variation. The two locations (Davis and Hopland) provided mainly a contrast in plane of nutrition. The results indicated that phenotypic variance was higher in the good environment (Davis) and heritability estimates were higher for 120 day weight and yearling weight. There was no evidence of large or important genotype-environment interactions for birth weight, weaning weight or yearling weight.

The importance of sire x plane of nutrition interaction for postweaning gain, body measurements, wool and carcass traits was evaluated by Osman and Bradford (1967) using 40 ram lambs and 78 wether lambs of grade Targhee, Corriedale and Targhee x Corriedale breeding. Significant sire x plane of nutrition interactions were reported for only five of the 38 comparisons made, indicating that the interactions were not a major source of variation.

Brown, Baugus and Sabin (1961) compared two inbred lines of Hampshire and crossbred lambs (Hampshire x range ewes) to determine the effects of sex x line interaction on birth weight, 30 day weight,

120 day weight and number of days to reach 27 kg. The interaction
effect was significant only for the number of days required by the
inbred lambs to reach 27 kg.

Significant interaction for gain to 6 months of age in ram lambs
and for gain to 12 months of age in ewe lambs was reported by Radomska
(1965) when comparing half sib progeny of Merino rams in two different
environments (flocks vs. test stations). No interaction for birth
weight or weaning weight was noted.

Vesely and Robison (1969), utilizing Rambouillet and Romnelet
lambs from 75 sires, investigated the importance of genotype x sex
interactions in sheep. Differences in heritability estimates between
the two sexes for the growth and fleece traits studied were small.
All genotype x sex interactions were nonsignificant in the Romnelet.
In the Rambouillet, only one sub-group showed significant sire x sex
interaction for some traits. The authors concluded that genotype x sex
interactions were not of enough magnitude or incident to be of
importance.

Results of the studies reviewed on genotype-environment inter-
actions in sheep are somewhat inconclusive. The study of Carter et al.
(1971a, 1971b) would suggest that these interactions, particularly for
fertility traits, may be more important when large differences in
genotypes and environments are involved.

Beef Cattle

Gestation length and calving ease. Relatively little information
is available on the importance of genotype-environment interaction on
gestation length and calving ease.

Edwards et al. (1966) found significant sire x region interactions
for gestation length in a British study of 8,750 calves sired by
Charolais and Hereford bulls out of Friesian, Ayrshire, Shorthorn,
Jersey and Guernsey dams and some purebred dairy calves. They also
observed significant sire x region interactions for difficult calvings
during one of the calving seasons.

Significant (P<.05) cow breed x year interactions for dystocia
score in female calves were reported by Sagebiel et al. (1969) in a
study of 529 calves of the Hereford, Angus and Charolais breeds and all
reciprocal crosses among them. However, none of the interactions of
bull breed x year in both sexes or cow breed x year in male calves were
significant for this trait.

Laster et al. (1973) studied various factors affecting dystocia
in Hereford and Angus cows bred to Hereford, Angus, Jersey, South Devon,
Limousin, Simmental and Charolais bulls. Significant (P<.05) breed
of sire x sex of calf and breed of sire x breed of dam x sex of calf
interactions were reported for calving difficulty.

An analysis of field records of Simmental sired calves by
Burfening et al. (1973) showed a significant (P<.01) effect for the
interaction of percent Simmental x sex of the calf on calving ease.

However, this same interaction was not significant for gestation length.

    <u>Birth weight</u>. Butts <u>et al</u>. (1971) studied two herds of Hereford cows, one originating at the U. S. Range Livestock Experiment Station, Miles City, Montana and the other at the Brooksville Beef Cattle Research Station, Brooksville, Florida. The two herds were sub-divided with half of each being transferred to the other location. Records analyzed during 1962-1968 indicated significant location x origin interactions (P<.01) for birth weight. Male and female calves of Montana origin were 2.9 and 3.6 kg heavier, respectively, at birth, than calves of Florida origin at the Montana location. Birth weights did not differ at the Florida location.

    A significant sire x region interaction for birth weight was noted by Edwards <u>et al</u>. (1966) in a study on the use of Charolais and Hereford bulls on cows of various dairy breeds in England and Wales.

    Ellis, Cartwright and Kruse (1965) observed a significant breed or cross x year interaction (P<.01) for Hereford, Brahman and crossbred calves of these two breeds. A later study by Turner and MacDonald (1969) found a significant breed of sire x year interaction for calves of various beef crosses. In comparing progeny of 11 Hereford sires at two locations in Montana (Bozeman and Miles City), Woodward and Clark (1950) found no significant sire x location interaction for birth weight.

    A study of five lines of Herefords by Brinks <u>et al</u>. (1967) revealed no significant line of sire or line of dam x year interaction for birth weight.

A review of literature reveals various studies involving the sex of the calf. In general, these interactions appear to be more important than the other kinds reviewed.

A differential sex response to inbreeding of dam and calf was reported by Brinks, Clark and Kieffer (1963). In this study, male calves were influenced more by inbreeding of the dam, while female calves were influenced more by inbreeding of the calf. Pahnish et al. (1964) found heritability estimates of birth weight to be 0.32 and 0.14 in male and female calves, respectively.

Ellis et al. (1965) observed a significant (P<.01) breed or cross x sex interaction with Hereford, Brahman and crossbred calves. A significant breed of sire x sex interaction (P<.005) was found by Laster et al. (1973) for calves from Hereford and Angus dams by seven different bull breeds.

Bradley et al. (1966), using records of Hereford and Hereford x Red Poll calves, found no significant sire x sex or breed of dam x sex interactions for birth weight. A study by Kress and Webb (1972) also reported no significant sire x sex interaction in analyzing records from one Hereford and one Angus herd. From a study of field records, Burfening et al. (1973) found no significant percent Simmental x sex of calf interaction.

Weaning weight. In the study of Butts et al. (1971) involving a reciprocal transfer of Hereford cattle between Montana and Florida,

significant (P<.01) location x origin interactions were noted for
weaning weight over a seven year period. Male and female calves of
Montana origin were 8.2 and 17.2 kg heavier, respectively, than calves
of Florida origin at the Montana location. At the Florida location,
males and females of Florida origin were 20.4 and 12.2 kg heavier,
respectively, than calves of Montana origin.

An analysis of data on 5,000 calves of several beef and dairy
crosses by Edwards et al. (1966) found significant sire x year, sire x
rearing method and sire x sex interactions for live weight at 90, 180
and 270 days of age. Brinks et al. (1967) observed significant sire x
year but not line of dam x year interactions for weaning weight of
female calves from crosses involving five Hereford lines. Similarly,
Urick et al. (1968) noted significant (P<.01) line of sire x year
interaction for female but not male calves in an analysis of data
involving the same Hereford lines. Line of dam x year interaction was
not significant for either sex.

Significant breed of sire x year interaction was found by Turner
and MacDonald (1969) in a study of several beef crosses.

The progeny of Hereford sires were tested at two locations by
Woodward and Clark (1950). No significant sire x location interaction
was noted for preweaning ADG. Rollins and Wagnon (1956) found no
significant difference in heritability estimates from two Hereford
herds on two nutritional levels. Harwin, Brinks and Stonaker (1966)
studied data on 1,627 inbred and linecross calves and found no