Sire by region interactions in Simmental sired calves
by Michael Walter Tess

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:

Field records from the American Simmental Association were used to evaluate sire x region interaction effects on weaning weight. Records were from 1/2- and 3/4-Simmental bulls and heifers born and weaned in the same herd and raised by their own dams. Two basic data sets were used. The A-data set was analyzed by least-squares procedures using a mixed model containing region, herd/region, sire, age of dam, sex, percent Simmental, sire x region (SXR) interaction effects and a regression on weaning age. Four large regions were outlined with each' region including several states. Sire and SXR interaction effects were both significant and their variance components comprised 1.0 and .2% of the total variance, respectively. The confidence interval for the genetic correlation overlapped unity. Rankings of the least-squares SXR means in each region indicated little changing of rank of the sires among regions. The B-data sets included only heifer records and 1/2- and 3/4-Simmental records were analyzed separately. The B-data sets were analyzed by least-squares procedures using a model containing region, herd/region, sire, age of dam, SXR, and sire x herd/region (SXH/R) interaction effects with a regression on weaning age. Three smaller regions were' outlined: Montana (MT), Midwest (MW=Iowa + Illinois), and Texas (TX). Each region was analyzed separately in the 3/4-Simmental data sets by subdividing each region into two subregions in order to assess any subregion effects. Because of large subregion effects within TX, the West-TX subregion was deleted. Each combination of two regions was then analyzed in both 1/2- and 3/4-Simmental data sets. Sire effects were significant in all 3/4-Simmental analyses but not in any of the 1/2-Simmental analyses. The sire variance component comprised an average of 1.8% of the total variance. SXR interaction effects were generally not significant but did approach significance (P=.06) in the 3/4-Simmental MW-TX analysis and was significant (P=.05) in the 1/2-Simmental MW-TX analysis. The SXR interaction variance component comprised an average of .8% of the total variance. Confidence intervals for the genetic correlations in each analysis overlapped unity. Rankings of the least-squares SXR means in each region in each analysis indicated that some changing of rank of the sires was occurring but was not of such magnitude to be of practical importance. SXH/R interaction effects were significant in all B-data set analyses. The variance component for the SXH/R interaction comprised an average of 4.5% of the total variance and was consistently larger than the sire and SXR interaction variance components. Results indicated that SXR interaction effects are not important. SXH/R interaction effects, however, were significant sources of variation in weaning, weights. Further evaluation of sire x herd interactions was suggested.

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MICHAEL WALTER TESS

A thesis submitted in partial fulfillment
of the requirements for the degree

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ABSTRACT

Field records from the American Simmental Association were used to
evaluate sire x region interaction effects on weaning weight. Records
were from 1/2- and 3/4-Simmental bulls and heifers born and weaned in
the same herd and raised by their own dams. Two basic data sets were
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action variance components. Results indicated that SXR interaction
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significant sources of variation in weaning weights. Further evaluation
of sire x herd interactions was suggested.

INTRODUCTION

The ability to accurately identify those animals that are superior genetically is essential in order to obtain maximum progress from selection over time. Genotype x environment interactions may be defined as the failure of the effects of genotypes and environments to be additive, or in other words, the failure of genotype to have the same effect on phenotype in different environments.

Genotype x environment interactions are important because of the potential problems and opportunities they represent to animal breeders. If important genotype x environment interactions exist, progeny testing programs might need to be expanded to include progeny from all those environments among which important interactions exist. On the other hand, specific genotypes might be utilized to provide faster progress in specific environments.

Beef cattle are raised in many different climates and under a wide range of management conditions. With the increased use of artificial insemination in the United States, sires can produce progeny virtually anywhere in the country. If genotype x environment interactions do exist in beef cattle, specifically sire x region interactions, then use of sires in many different regions may need to be preceeded by progeny testing in each region in which a sire is to be used. Studies in beef cattle are not conclusive as to the presence and/or importance of such interactions.

The purpose of this study was to determine if sire x region interactions exist in weaning weights of Simmental sired calves and if so to evaluate the importance of such interactions.

LITERATURE REVIEW

Introduction

The existence of genotype x environment interactions was proposed by several scientists before 1950, but little experimentation was conducted before that time. Wright (1939) stated "Where there are hidden systems of factor interactions, selection must be based on persistent combinations, and the method indicated is to start numerous isolated, strains, sufficiently widely founded to allow selection within each, ..." Lush (1945) recommended that selection should be carried out in the environment in which the animal is expected to perform, conceeding the possible presence of important interactions between genotype and environment.

Dobzhansky (1960) stated "Heredity does not determine traits; it determines, ..., the 'norm of reaction' of the organism to the environment. Different environments evoke different reactions in organisms with similar heredities; different hereditities engender different reactions in organisms which develope in similar environments."

An opposing view presented by Hammond (1947) seemed to be the catalyst for research in genotype x environment interactions. He stated "Since the actions of genes on the characters of an animal is limited to those effects which are physiologically possible, selection is most effective when carried out under environmental conditions which favour the fullest expression of the character that is particularly desired."

In a response to Hammond, Falconer (1952) restated the recommenda-
tions of Lush and said that situations involving genotype x environment
interactions may be treated by methods of genetic correlation. In this
manner performance in two environments is regarded as two characters
genetically correlated. Falconer maintained that this procedure
would give a specific answer as to whether selection should be done in
an optimum environment or in one in which the animal is expected to
live.

Robertson (1959) presented methods of estimating genetic correla-
tions from the components of variance from a two way analysis of
variance. He stated that interactions may be due to two completely
separate biological phenomena. First, the between group variance
may be different and second, the actual rankings of the genotypes
may be different. He further proposed that a genetic correlation of
.8 or less was of biological importance.

Dickerson (1962) expanded upon the work of Robertson and demon-
strated similar methods of estimating genetic correlations from
variance components in an analysis of variance. He proposed that
one of the most probable kinds of genotype x environment interactions
is a shift in emphasis between traits as environment changes. For
example, selection for growth rate in a temperate climate might
emphasize feed efficiency and/or appetite, whereas selection for
growth rate in a humid climate might emphasize resistance to heat.

Yamada (1962) presented formulae for calculating genetic correlations in a mixed model situation, or in other words, when environments are considered as fixed rather than random in the model.

Falconer and Latyszewski (1952) reported on an experiment which supported the existence of genotype x environment interactions. Two strains of mice, derived from a single foundation population, were selected in the same manner for body weight at 6 weeks of age. One strain was fed ad libitum and the other fed at 75% of normal food intake. After several generations, portions of both strains exchanged diets. When both strains were fed on the restricted diet the 'restricted line' was superior, with the 'full line' showing no improvement over the unselected level. On the ad libitum diet the 'full line' was superior but the 'restricted line' was very close to the 'full line' performance and showed marked improvement over the unselected level. Falconer and Latyszewski concluded that their results contradicted Hammond's thesis.

Falconer (1960) reported on a similar experiment in which selection was made in two directions (increased and decreased growth) in mice raised on both high and low planes of nutrition. In mice selected for increased growth, growth on the high plane of nutrition was increased equally by selection at both nutritional levels, but growth on the low plane of nutrition was increased only by selection at the

low plane of nutrition. In mice selected for decreased growth,
growth on the high plane of nutrition was reduced only be selection
at the high plane of nutrition, but growth on the low plane of
nutrition was reduced equally by selection at both nutritional levels.
Falconer concluded that if good performance under a variety of con-
ditions is desired, the selection should be made under the conditions
least favorable to the desired expression of the trait.

Haldane (1946) demonstrated that with m genotypes and n environ-
ments there are $\frac{(mn)!}{m!\ n!}$ possible kinds of interactions. Many
individuals have attempted to classify these many combinations into
more simple meaningful categories. Haldane (1946) put forth six
basic types of interactions between two environments and two genotypes.

McBride (1958) and Dunlop (1962) proposed interaction classifica-
tions based on those combinations of environments with large or small
differences and genotypes with large or small differences. Small
environmental differences may be thought of as fluctuations within
a general area in which a population lives and large differences are
those of climate, management practices, or regions. Small genotype
differences are those within a herd or related herds with large
differences being those between breeds, strains or species. These
interactions are illustrated in figure 1. McBride suggested that
interactions of importance would be most often found involving large
environmental differences and either large or small genetic differences.
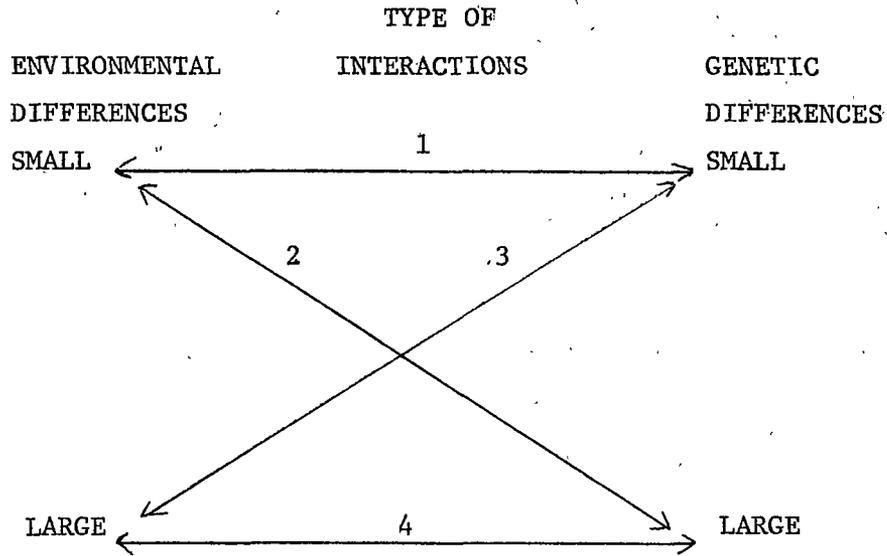
Figure 1.   Types of heredity x environment interactions
(Dunlop, 1962).

Pani and Lasley (1972) proposed a different classification of genotype x environment interactions involving two environments and two genotypes with consideration made for statistical significance of such interactions (figure 2). This classification makes a distinction between significant interactions involving changes in magnitude and those involving changes in rank. Differences in magnitude of interactions might suggest optimum environments in which selection might be made for detection of true genotype differences. Changes in rank are important when selection is performed in a different environment than which the animals or their progeny are expected to live.

Dairy Cattle

Extensive research in genotype x environment interactions has been done in dairy cattle. It might be argued that due to the intensive management of dairy cows compared to beef cattle that environmental differences within the dairy industry are of a different nature than those of the beef industry. Also, the traits most commonly investigated in dairy research are different than those of the beef industry. Conceding these differences, the limited amount of literature in preweaning traits in beef cattle makes the dairy literature of considerable value.

Milk yield and fat percent. Bonnier et al. (1948), in studies with identical twins, observed interactions between heredity and environment of growth, preweaning and postweaning, milk yield and fat
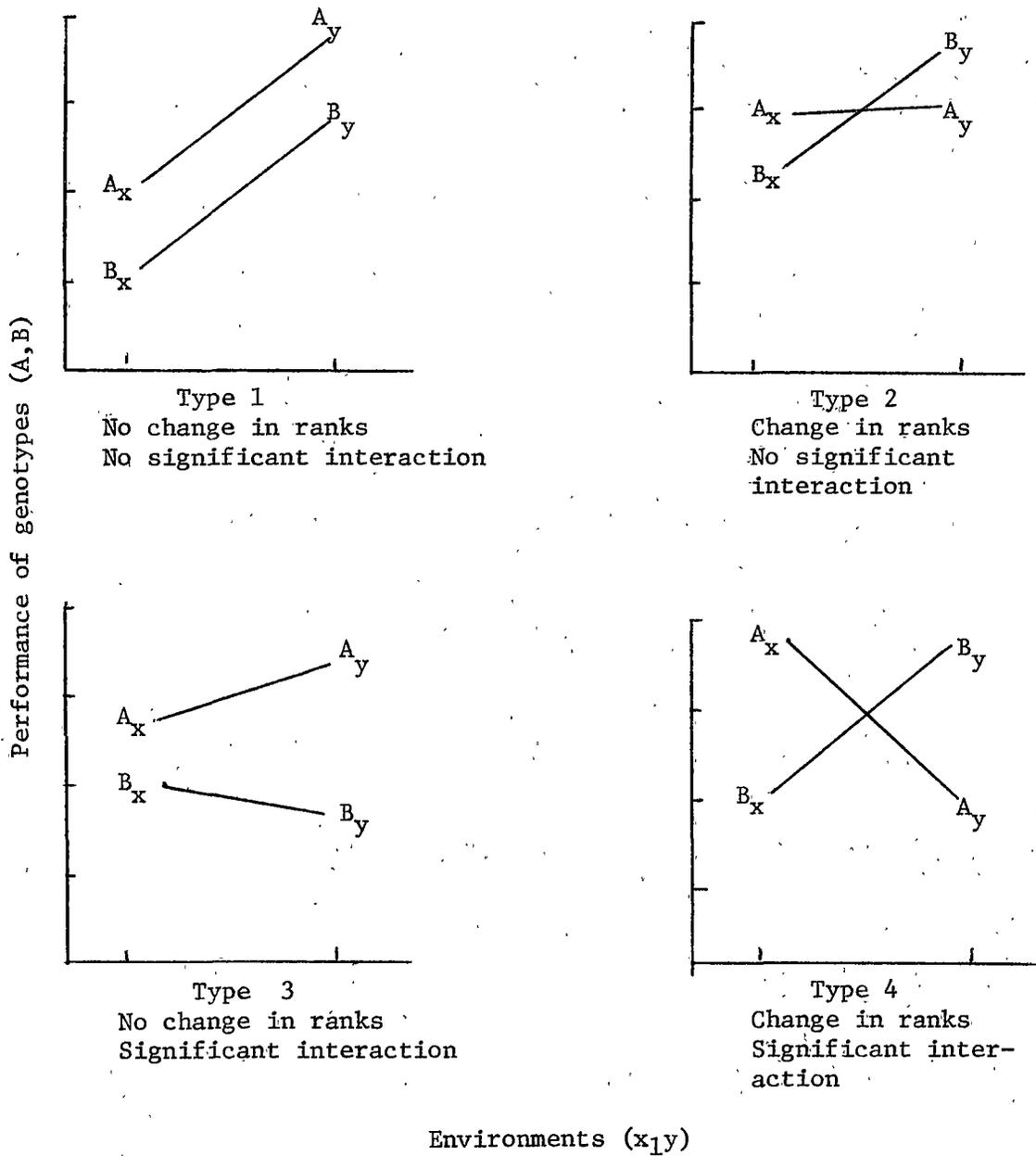
Figure 2. Classification of genotype x environment interaction
(Pani and Lasley, 1972).

percent. He also observed non-linear interactions between age and heredity in weight and height of the shoulder, and between stage of lactation and heredity in milk yield.

In another study with identical twins, Brumby (1961) found evidence of interactions between herd environment and genotype which composed an appreciable source of variation.

Freeman (1969) studied identical and fraternal twins raised on two diets. The pair x ration interaction estimated from 30 to 55 identical pairs of various ages was zero for first lactaion milk yield.

In studies of milk yield in Michigan DHIA records from 8,638 Holstein and 1,872 Guernsey cows, Burdick and McGilliard (1963), found no interactions of practical importance between sires and herd environments classified by level of production, location, days dry, calving interval, or type of housing.

Mao and Burnside (1969) studied the milk production records of AI sired cows and found no important interactions between sire proofs and herd environments classified with respect to use of AI sires, price received for milk, source of water on pasture, forage feeding method in winter and summer, amount of exercise in winter, and herd size. They did find an interaction (P<.01) between sire proofs and level of grain feeding in summer.

Probably the most common type of genotype x environment inter-
actions studied in dairy cattle are sire x herd interactions. Legates
et al. (1956), in studying lactation production records of 24,754
daughters of Guernsey, Holstein, and Jersey sires used in U.S. AI
associations, found sire x herd variances to be inconsequential for
milk, fat percent, and fat yield.

Mason and Robertson (1956) studied 13,000 milk records of AI
sired cows in Denmark. They divided herds on the basis of average
production levels. No evidence was found of any sire x herd inter-
actions for milk yield or fat content.

Van Vleck (1963) divided 45,876 first lactation and 39,261 second
lactation records of New York AI sired cows into four groups on the
basis of DHIA season averages. No important sire x herd interactions
were found.

Age-corrected milk records of 40,374 Holstein cows tested in 1,073
herds divided on the basis of herd production levels were studied
by Burnside and Rennie (1968). Correlations among contemporary
comparison proofs of 19 sires, each evaluated on the production of
at least 20 daughters at four levels of herd production ranged from .73
to 1.01 indicating little changing in rank.

McDaniel and Corley (1967) studied the first lactation records of
AI progeny of 40 Holstein sires, each with at least 1000 daughters.

Correlations amoung sire progeny averages at different herdmate levels
were all very high (.88 to .96) suggesting bulls ranked in about the
same order at all levels.

Records of 57 Friesian, 8 English Ayrshire, and 11 Scottish
Ayrshire AI sires were used by Robertson et al. (1960) to compile
contemporary comparisons. For each bull, herd-years were divided
into three groups on the basis of yield with comparisons being made at
each level. Correlations between true breeding values of the bulls at
different levels were close to unity. They concluded that no sire
x herd interaction was indicated.

Wiggans and Van Vleck (1970) classified over 1,000 Holstein herds
in New York's Dairy Herd Improvement Cooperative as to the type of
housing system used (free stall or stanchion). A total of 21,285
first-lactation records were analyzed. The genetic correlation
between sire effects in the two systems was near unity suggesting
essentially complete agreement between sire rankings in the two housing
systems.

Sire x region interactions in first lactation records of 10,548
daughters of 46 Holstein sires born in the North and the South were
investigated by Lytton and Legates (1966). Correlations of average
breeding values of sires in the two regions were essentially unity.
Estimates of the sire x region interaction variance were also zero.

They concluded that influences associated with a particular region should not unduly confuse the ranking of sires in the different regions.

Comparisons of AI sired heifers to non-AI sired heifers were made by Wadell and McGilliard (1959) from Michigan DHIA records. No interaction between AI sires and herds existed when each daughter's record was expressed as a deviation from the average fat production of all non-AI cows in the same herd.

Van Vleck et al. (1961), in studies of first and second lactation records of daughters of Holstein AI sires, found that sire x herd and sire x year-season interactions were both small indicating little genotype and environment interaction. Kelleher et al. (1967) also studied bull x herd-year season interactions and found that the interaction component only accounted for 2% of the variation in milk yield.

Branton et al. (1974) studied season of calving and its interactions with genotype in five herds in Louisiana. The sire x season interaction accounted for less than 1% of the total variation in both milk yield and milk fat.

Heritability. In his paper on genotype x environment interactions, Falconer (1952) stated that it is possible for a correlated response to be greater than direct response to selection if the heritability of the correlated character is greater than the heritability of the character in questions and the genetic correlation between the two

characters is large. The correlated character in the present context is the expression of the trait in a different environment. This has stimulated several experiments and studies into the heritability of milking traits in different environments. Considerable attention has also been given to the nature of phenotypic and genetic variances in different environments, which of course are closely related to heritability.

Milk production records from 5,740 first lactation Holstein daughter-dam pairs were analyzed by Van Vleck and Bradford (1964) to determine if heritability was related to herd production level. Heritability of milk yield from daughter-dam regressions was essentially constant at ten environmental levels. Estimates of heritability from paternal half-sib correlations over four environment levels and based on data from 2,568 daughters of AI sires generally increased as herd level of production increased. Daughter-dam estimates of heritability from the same data were essentially constant over the four levels. Total variance generally increased as herd level of production increased.

Mason and Robertson (1956) reported that heritability of milk yield and fat content and the variance of yield within herds increased as yield increased. Also the genetic variance was five times as large in high-yielding herds as in low-yielding herds. Van Vleck (1963) also found that higher producing herds had greater variability and increased heritability. Robertson et al. (1960) reported the

variance of yield within groups and the variance between groups increased with production level, but heritability remained the same.

Touchberry (1963) analyzed the records of 20,024 Holstein daughter-dam pairs from 1,703 herds. Herds were divided into 20 classes on the basis of production average. Heritability estimates for milk yield did not change with production level, although both phenotypic and genetic variances increased. Heritability for percent fat increased significantly with production level, but phenotypic variance decreased while genetic variance increased. Heritability for milk-fat decreased as production level increased, while both phenotypic and genetic variances increased.

Records of 1,243 Swedish red-and white cattle from 12 low- and 17 high-producing herds for butterfat were studied by Johansson (1953). Bulls of the same or related lines were used in both herd types so it was assumed that genetic differences were small. Heritabilities for yield and fat percent did not change significantly between herd levels.

Heritability estimates were calculated by Legates (1962) to examine the relationship between these values and the herd level of fat yield for 1,825 Guernsey, 5,458 Holstein, and 3,465 Jersey daughter-dam pairs. He reported that phenotypic and additive genetic variances increased as mean fat production for herd increased, but there was no significant relationship between heritability values and production levels for the groups of herds within any of the breeds.

Sheep

Regional environmental differences in the sheep industry would seem to be more similar to those in the beef industry than is the case in dairy cattle. Variation in types of management practices in both the sheep and the beef industry appear to be much greater than in the dairy industry. Based on this assumption, Pani and Lasley (1972) proposed that genotype x environment interactions are more likely to be important in sheep and beef cattle than for dairy cattle and poultry. Studies of several traits of economic importance in sheep are reviewed below.

Birth Weight. Osman and Bradford (1965) collected data at two locations in California over 5 years. One location, Hopland, represented a poor environment, and the other location, Davis, represented a good environment. Results indicated that the heritable fraction of variance was larger at Davis than at Hopland. However, no significant genotype x environment interactions were observed for birth weight.

Half-sib progeny of five Merino rams, each from a different flock, were investigated in different flocks and at a progeny testing station by Radomska (1965). No interaction due to the different environments and types was found in birth weight.

Hohenboken et al. (1976b) reported genetic, environmental and interaction effects from a diallel cross among three breeds replicated

over 3 years and two grazing management systems (improved dryland hill
pasture versus fertilized, irrigated pastures). No significant
genotype x environment interactions were found for birth weight.

Two breed crosses were studied at both Ottawa, Canada, and Glade
Springs, Virginia, by Carter et al. (1971a). The same rams were used
at both locations during the test. A significant (P<.05) ewe breed
cross x location interaction was reported for birth weight, but
differences were relatively small.

Weaning Weight and Preweaning Average Daily Gain. Five strains
of Australian Merinos raised in three different wool-growing regions
in Australia were evaluated by Dunlop (1963). Strain x location inter-
actions were generally of moderate or small size and accounted for
only a small fraction of the total variance in weaning weight.
Radomska (1965) and Osman and Bradford (1965) also found genotype x
location interactions not to be significant for weaning weight. Carter
et al. (1971b) found the ewe breed cross x location interaction to be
of marginal importance for weaning weight (P=.07). Hohenboken et al.
(1976b), however, reported a significant sire breed x management
system interaction for weaning weight.

Ercanbrack and Price (1969) reported on a study designed to
compare the effects of early weaning to regular weaning using 173
inbred and 397 non-inbred Rambouillet, Targhee, and Columbia sheep.

No significant interaction was observed between breed and weaning response in the inbred sheep but they did observe a significant inter- action in the non-inbred sheep.

Postweaning Gain. Osman and Bradford (1965) and Carter et al. (1971b) both reported no evidence of important genotype x location interactions for average daily gain. Radomska (1965), however, found a significant genotype x environment interaction in development to 6 months of age in ram lambs and to 12 months of age in ewe lambs. Hohenboken et al. (1976b) found a significant sire breed x management system interaction for carcass weight per day of age.

Several studies of postweaning performance in sheep have classi- fied environments according to the plane or type of nutrition. King and Young (1955) studied the reactions of three breeds of sheep (Blackface, Cheviot, and Wiltshire) to different environments classified according to temperature and plane of nutrition. Evidence was obtained that the three breeds reacted differently to these environments. No change in rank occurred between the environments but the Blackface grew relatively faster on a good plane of nutri- tion than the other two breeds.

Morely (1956) divided a number of groups of half-sibs into two lots, one on a high plane of nutrition and the second on a low plane of nutrition from 3 to 17 months of age. Genotype x treatment interactions were not important for 6-month body weight, but were

large and highly significant for weight at 12 and 17 months of age.
Heritability did not vary with plane of nutrition.

Responses of 150 twin lambs of various breeds and crosses to
different planes of nutrition were invesigated by King et al. (1959).
Results indicated that the different genotypes responded similarly to
the different planes of nutrition. Few interactions were found of
statistical significance.

Osman and Bradford (1967) used 40 ram lambs sired by five sires
and 78 wether lambs sired by eight sires to study the effects of sire
and two levels of nutrition over two, 7 week periods. Significant
interactions between sire and plane of nutrition were found for
average daily gain and daily feed intake in weithers in period one, and
for carcass weight in rams during period two. Significant inter-
actions were found in only five of 38 comparisons which led these
researchers to conclude that this interaction was not a major
source of variation.

The performance of 324 ram lambs from eight breeds averaging
84 days in age and 28 kg in weight were analyzed by Glimp (1971) to
study the effects of breed and ration energy level on rate and
efficiency of gain. Breeds used were Suffolk, Hampshire, Targhee,
D-line, Fine Wool, Course Wool, Corriedale, and Navajo. Suffolk
and Hampshire gained faster when the ration energy level was increased,
but the other breeds showed no change, which produced a significant

(P<.01) breed x ration interaction.

Wool Traits. Radomska (1965) reported a significant interaction between genotype and location in wool fineness at the second shearing but found no important interactions for several other wool and fleece characters including fleece weight at the second shearing. Osman and Bradford (1967) in the same study mentioned above, out of several trait and period combinations, found only staple length in wethers during period one and clean fleece weight during period two to exhibit significant sire x plane of nutrition interactions. Morley (1956) reported genotype x plane of nutrition interactions were not important for any fleece characters.

Dunlop (1962) presented results for greasy fleece weight, clean fleece weight, percent clean scoured yield, number of fibers per unit area of skin, number of crimps per inch of staple, fiber diameter, staple length, gradings of count, character, color, soundness and handle from his experiment involving five strains of Merinos raised in three regions of Australia. Real interactions were found in most traits but were generally small and accounted for only a small fraction of the total variance. He concluded that specific adaptations in these characteristics should not be an important reason for the choice of the strain of sheep to be used in particular areas.

In a later study, Dunlop (1966) analyzed the records of the
female progeny of the rams used in the previous experiment. Clean
wool weight was analyzed for the presence of ram x year, ram x drop,
and ram x station interactions. The ram x station interaction was
found to be significant and its variance component was approximately
half as large as the sire component of variance. The ram x drop and
the ram x year interactions were not significant sources of variation.

Ewe Performance. Strain x location interactions were reported to
be not important by Dunlop (1963) for the number of weight of lambs
born and weaned. Carter et al. (1971a) found significant breed x
location interactions for lambing date (P<.01) and for weight of lamb
weaned per ewe mated (P<.05), and an interaction of marginal importance
(P=.08) for percentage of ewes lambing over a 5 year period. It should
be noted that the breeds used in the study of Carter et al. (1971a)
probably represented more diverse genotypes than the strains used by
Dunlop (1963).

Hohenboken et al. (1976a) found no important sire breed x
management system or sire breed x year interactions for ewe fertility
and productivity. Dam breed x management system interactions, however,
were found to be significant with changes in rank occurring between
the breeds for ewe fertility and productivity.

Genotype x Sex Interactions. Sex is an important source of
environmental variation when considering the progeny of a sire or dam.
An interaction between genotype and sex would indicate a differential
response to sex between genotypes.

Brown et al. (1961) analyzed the records of 121 inbred and 132
crossbred lambs to determine the effects of line, sex, type of birth,
age of dam, and the sex x line interaction on birth weight, 30-day
weight, 120-day weight and days required to reach 27 kilograms.
Results indicated that the sex x line interaction was only significant
in the case of days required to reach 27 kg in the inbred lambs.
Interactions for all other traits were not important.

Data from 1,947 Rambouillet and Romnelet lambs sired by 75 rams
was analyzed by Vesely and Robison (1969). Birth weight, weaning
weight, grease and clean fleece weight, staple length, wool grade,
wool yield, average daily gain, total gain, feed efficiency, and final
weight were studied to determine the presence of genotype x sex inter-
actions. All genotype x sex interactions were not significant in the
Romnelet and only one sub group (10 sires within 1 year) had a
significant (P<.05) interaction in the Rambouillet. Nine of 11 traits
gave higher heritabilities in females in the Romnelet, with all
differences being small. The researchers concluded the similarity in
heritability in the two sexes and the absence of important sire x sex
interactions indicated that such interactions are not of sufficient

incidence or magnitude to be of concern in selection programs.

Beef Cattle

Birth Weight. Differences between years often account for a considerable portion of the variation in growth traits. Years can reflect changes in many environmental factors such as rainfall, pasture conditions, and management practices. Ellis et al. (1965) analyzed birth weight data collected over 11 years in Texas, and reported a significant breed or cross x year interaction (P<.01).

Turner and MacDonald (1969) studied the preweaning data from approximately 1,100 straightbred, singlecross, backcross, and three-breed-cross calves of Angus, Brahman, Brangus, and Hereford breeding and crossbred calves sired by Charolais bulls. The year x breed of sire interaction was not important for birth weight.

Brinks et al. (1967) analyzed the records of 241 bull and 228 heifer calves from five inbred lines produced over several years. Line of sire x year and line of dam x year interactions were not found be be significant for birth weight.

Sire x location interactions were studied by Woodward and Clark (1950) using the records of steer progeny produced at two locations in Montana and sired by 11 bulls. No significant interaction between sire and location was observed for birth weight.

The performance of 8,750 calves sired by Charolais and Hereford bulls out of Freisian, Ayrshire, Shorthorn, Jersey and Guernsey dams or purebred dairy was compared by Edwards et al. (1966). The calves were born in England and Wales. Birth weight was found to be significantly affected by the sire x region interaction.

Butts et al. (1971) reported on an experiment involving the reciprocal transfer of half of two herds of Hereford cattle between Brooksville, Florida, and Miles City, Montana. During the first 7 years of the experiment important (P<.01) genotype x location-orgin interactions were found for birth weight.

Field records of Simmental sired calves from several regions of the United states were analyzed by Nunn et al. (1978). They reported no significant sire x region interactions for birth weight.

Friedrich (1977) analyzed field records of non-creep fed Simmental-cross calves for sire x management unit interactions and analyzed records from creep fed and non-creep fed calves for sire x sex interactions. A significant sire x management unit interaction was found for birth weight in three-quarter Simmental calves, but not in half Simmental calves. Sire x sex interactions were significant in all analyses.

The effects of sex and sire were investigated by Bradley et al. (1966) in 34 Hereford and 33 Hereford x Red Poll steer and heifer calves sired by two Hereford sires. Interactions between sex and sire

and between sex and breed of dam were found to be small and not significant for birth weight. Ellis et al. (1965), however, found sex x breed or cross effects to be very important (P<.01).

Records of Angus and Hereford calves sired over several years were analyzed by Kress and Webb (1972). Interactions between sex and year, dam, and sires within years were not significant for birth weight.

Pahnish et al. (1964) reported that the heritability of birth weight was .32 for bulls and .14 for heifers in a study involving 350 heifer and 370 bull calves produced over a 4 year period.

Weaning Weight and Preweaning Gain. Burnside et al. (1972) fed 48 pairs of male Holstein fraternal twin calves two different rations. Some pairs were fed uniformly and others were split between the two rations. No evidence was found for a pair x ration interaction in growth traits.

Heritability estimates for weaning weight at 240 days in two herds of similar breeding were calculated by Rollins and Wagnon (1956). One herd was supplemented, the other was not. They concluded that differences in nutritive levels between the two herds did not influence heritabilty.

Brinks et al. (1967) reported significant (P<.05) line of sire x year effects for heifers but not for bulls in weaning weight. Turner

and MacDonald (1969) also found significant (P<.05) breed of sire x

year and breed of sire x mating type interactions for weaning weight,

however, the ranking of the mating types generally was the same for

each breed of sire. Similarly, Edwards et al. (1966) reported signifi-

cant sire x year and sire x rearing method interactions for growth

traits.

Woodward and Clark (1950) found no significant sire x location

interaction for weaning weight in Montana. Butts, et al. (1971) found

highly significant genotype x location-origin interactions between

Montana and Florida. Nunn et al. (1978) also reported significant

sire x region interactions over several regions of the United States.

Data on 228 male calves sired by 17 Flechvieh and 3 Gelbvieh

sires in West Germany (144) and Central Texas (84) were analyzed by

Aken et al. (1976). Calves in West Germany were purebred while the

calves in Texas were crossbred. The sire x location interaction was

not significant for weight at 196 days of age.

Sire x management unit effects were found to be significant for

weaning weight and preweaning gain in three-quarter Simmental calves

but not for half Simmental calves by Friedrich (1977).

Wilson et al. (1972) studied herd, sire, and herd x sire inter-

action effects in data from progeny tests of Angus and Hereford bulls,

each replicated in different herds of each breed. Weaning records

obtained from 976 steers sired by 55 bulls. The herd x sire inter-
action was not significant.

Many researchers have investigated genotype x sex interactions
in preweaning growth traits. Knapp et al. (1942) studied data
collected in Montana over 3 years. They observed one sire which pro-
duced heifers averaging 12 kg heavier than male calves and this sire
produced proportionally heavier heifers than steers when compared to
other bulls. There was no significant sire x sex interaction for
weaning score.

Weaning weights of 419 steers and 444 heifer calves were studied
by Koger and Knox (1945) under range conditions over several years.
No sire x sex interaction was observed for weaning weight. The sires
in this study were related which led the authors to conclude that
variation in sires was probably less than what would be obtained from
a group of unrelated sires.

Bradley et al. (1966) reported no significant sire x sex inter-
actions for preweaning average daily gain, weaning weight, and weaning
type score. Edwards et al. (1966), however, reported important sire
x sex interactions for growth traits. Similarly, Kress and Webb (1972)
found significant sire x sex interactions for preweaning average
daily gain in Angus calves (P<.01) and for preweaning average daily
gain and weaning weight in Hereford calves (P<.05), with significant
changes in rank of sires occurring. Friedrich (1977) also reported

significant sire x sex interactions for preweaning gain and weaning weight.

Pahnish et al. (1961) studied sex and sire influences on weaning weights of 329 bull and 332 heifer calves produced on two ranches over 6 years. The sire x sex interaction within years and ranches was not significant. Heritability of weaning weight was found to be .28 for bulls and .57 for heifers. In a later study, Pahnish et al. (1964) reported heritability of weaning weight to be .05 for bulls and .23 for heifers.

Sex differences in response to inbreeding in a single closed line of Hereford cattle were reported by Brinks et al. (1963). Data included 1,041 male and 986 female calves produced at the U. S. Range Livestock Experiment Station in Miles City, Montana. Partial and standard partial regressions, calculated within sire-year subclasses, indicated that inbreeding of the calf had a more pronounced effect on females and inbreeding of the dam had a greater effect on males.

In a crossline experiment involving five inbred lines of Hereford cattle, Brinks et al. (1967) reported that greater heterosis was exhibited for preweaning daily gain and weaning weight in heifers than in bulls.

Harwin et al. (1966) analyzed weaning weight records of 1,627 inbred linecross Hereford calves. A significant sex x mating system interaction was found due to the greater expression of heterosis in heifers than in bulls.

Wilson et al. (1969) analyzed data from 80 steers and 94 heifers

born from 1963 to 1966. The calves were all the progeny of 11

Polled Hereford bulls out of Angus-Holstein dams. A significant (P<.01)

sire x sex interaction in 205-day weight was observed with a true change

in rank among the sires between sexes.

Sire x sex interactions and sex differences for preweaning growth

rate and weaning weight were investigated by Tanner et al. (1969) using

data from 487 bull, steer, and heifer calves sired by 24 bulls. No

significant sire x sex interactions were observed for growth traits.

Postweaning Traits. Hereford (3/4)-Brahman (1/4) crossbred calves

were compared to straightbred Hereford calves by Rollins et al. (1964)

in the Imperial Valley of California which is characterized by

extremely hot summers and mild winters. The crossbred calves out-

gained the straightbred calves in the summer on pasture and in the

feedlot. The straightbred calves, however, performed best during

the fall and winter. This was described as a 'breed' x season

interaction.

Pani et al. (1973) investigated sire x year interactions in

postweaning traits of 411 male and 465 female yearling sired by 17

bulls in Missouri. Traits studied were average daily gain in the

feedlot, gain on pasture, conformation score, and weights at 392 and

550 days of age. No sire x year interactions were significant except

for yearling weight in bulls.

Averdunk et al. (1968) studied the daily weight gains from 140 days of age to 500 kg live weight on 97 progeny of nine sires at two testing stations. The sire x station interaction was not significant.

One hundred-two progeny of five AI sires were used by Dillard et al. (1964) to study sire x location interaction effects between two locations in North Carolina. Half the cattle at each location were fed in a feedlot and half on pasture. A total of 25 traits and measurements were considered and in general little evidence of interaction between sires and locations or sires and rations was found.

In a similar experiment in North Carolina involving three locations and two different rations, Ahlschwede et al. (1969) reported sire x ration and sire x location interactions effects were both not significant. Sires constituted a wide sample of the Hereford breed and the rations were very different.

Aken et al. (1976) reported a significant sire x location interaction for weight at 364 days of age but not at 280, 420, or 500 days of age. The one significant interaction did not involve a change in rank of the sires and when sires within breed x location was substituted for the sires x location interaction in the model there were no significant interactions.

Butts et al. (1971) reported important (P<.01) sire x location-origin effects for yearling weight, and Woodward and Clark (1950) reported significant (P<.05) sire x location interactions for feedlot gain and efficiency.

Wilson et al. (1972) found sire x herd interaction effects not to be important for postweaning traits.

Progeny of 34 sires were compared by Lagos and Cartwright (1963) under two feeding regimes in two experiments for weight gain over 140 days. In the first experiment, 56 Santa Gertrudis heifers from 10 sires were split by sire into a high concentrate feedlot group or on pasture with a concentrate supplement. The second experiment involved 67 Hereford steers from nine sires and 120 F_1 Brahman-Hereford steers from 15 sires split by breed and sire into two feedlot groups based on high and low concentrate rations. All sire x ration interactions were not signficant in both experiments, however, the additive variance increased under the higher plane of nutrition.

Warwich et al. (1964) studied the response of 25 pairs of identical twins to two rations (high and low concentrate) in gains to 800 pounds. Significant (P<.05) pair x ration interactions were reported for average daily gain and feed efficiency.

In a similar study using identical and fraternal Holstein twins assigned to high and low concentrat rations, Freeman (1969) found pair x ration interactions small for growth traits.

Kress et al. (1971) collected data on 15 sets of identical twins and 14 sets of fraternal twins fed on high and low concentrate rations. Set x diet interactions were not significant for 10 body measurements taken from 210 to 701 days of age. Genetic correlations were all

positive and near one suggesting little change in rank of sets between diets.

Postweaning gains of 42 groups of progeny (408 performance tested bulls and 402 limited fed heifers) were studied by Brown and Gacula (1962). Management and sex were confounded and referred to as 'environment'. The sire x environment interaction was not significant for average daily gain.

Urick et al. (1968) reported on a followup study of the preweaning traits published by Brinks (1967). Data was collected from 229 bulls and 226 heifers at Miles City, Montana, to estimate the amount of heterosis in postweaning traits resulting from the crossing of five lines of inbred Herefords. Heifers showed more heterosis than bulls for weights at all ages.

Thrift et al. (1970) tested 78 progeny of eight bulls on a postweaning feeding trial. The sire x sex interaction was not important for growth traits.

Sire x sex and breed of dam x sex interactions were found to be not important for postweaning gain and final weight by Bradley et al. (1966). On the other hand, Knapp et al. (1942) found a significant sire x sex interaction for average daily gain.

Age and weight at puberty were studied by Wiltbank et al. (1969) in Angus, Hereford, and crossbred heifers raised under two different feed levels. Crossbreds on the high nutritional level were heaviest,

but lightest at the low level producing a significant (P<.01) breed x nutrition interaction for weight at puberty.

Carcass Traits. Thrift et al. (1970), Tanner et al. (1970), and Wilson et al. (1969) all found sire x sex interactions not important for carcass traits.

Records of three calf crops produced by Hereford and Charolais cows bred to Hereford and Charolais bulls were studied by Klosterman et al. (1968). Half of the calves were creep fed, fattened immediately following weaning and slaughtered at 14 months of age. The other half of the calves were not creep fed, wintered, grazed for about 60 days, fattened in dry lot and slaughtered at 20 months of age. Significant interactions were found between breed and management system for weight of edible portion produced per day of age and in marbling score.

Forty-eight pairs of Holstein fraternal twins raised on two rations were used by Batra et al. (1973) to study ration x pair interactions for loin circumference, loin width, thurl width, pelvis length, and length from stifle to stifle. Carcass weights were also taken. No significant ration x pair interactions were found for the live measurements and the only important interactions in carcass traits were for percent kidneys, percent fat in shoulder, kidneys and minor cuts and bone in flank and breast.

MATERIALS AND METHODS

Data used for this study were supplied by the American Simmental Association from their 1977 sire evaluation program. These records were the progeny records of Simmental sires used primarily by artificial insemination throughout the United States, representing 3 years data (1974 to 1976).

Two basic data sets were used, and were identified as A and B. The A-data set was divided into geographic regions and edited on a basis similar to that of an earlier study made at Montana State University by Nunn et al. (1978), in order to specifically compare analyses made over different years. The United States was divided into four regions as outlined in table 1.

In the B-data sets the United States was divided into geographic regions on the basis of elevation, soil type, and climate differences (Austin, 1972). Regions were outlined so that each region was separated by considerable distance from other regions to be as distinct from all other regions as possible. After consideration of the number of records available in each state four major region designations were made. It was not possible to outline regions in the far West and the East because of insufficient record numbers in both areas. Region designations were as follows: Montana, Midwest (Iowa and Illinois), Texas, and Southeast (Louisiana, Mississippi, Alabama, and Georgia).

TABLE 1. REGION DESIGNATIONS FOR THE A-DATA SET.

Region 1	Minnesota
	Iowa
	Missouri
	North Dakota
	South Dakota
	Nebraska
	Kansas
Region 2	Oklahoma
	Texas
Region 3	Montana
Region 4	Idaho
	Wyoming
	Colorado
	New Mexico
	Arizona
	Utah
	Nevada

Each region was further subdivided into two subregions on the basis of the same criteria as the major regions and with consideration for the number of records available in each region. This was accomplished by use of the zip code numbers corresponding to the owner location. Basically, all region subdivisions were made between East and West (figure 3).

Each region was analyzed separately to assess any subregion effects and/or interactions between sires and subregions. On the basis of the results from these analyses, modifications of the major regions were made to make each region as distinct as possible from other major regions and as uniform within as possible.

If regions are actually composed of two or more subregions which are very different, interpretation of any sire x region interaction effects becomes difficult. For example, it is possible that sub-region effects opposite in sign (or direction) could be averaged when considered as only one region and could yield reduced region and/or sire x region interaction effects.

Each possible combination of two major regions was then analyzed to assess sire x region interaction effects.

Since the data were composed of field records collected without supervision, completeness of the records varies and the records may be subject to greater error than data collected in a designed and controlled experiment. For these reasons various edits were