Some factors affecting performance in three closed lines of Hereford cattle

by Donald Charles Anderson

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:
The influence of years, lines, age of dam, years x lines, inbreeding of dam, inbreeding of calf, and weaning age, on performance traits in three closed lines of Hereford cattle was studied. Data were collected over a 14-year period at the North Montana Branch Experiment Station. Records from dams of three closed lines and their subsequent calf production were included in a least squares analysis. Heifer and bull calves were analyzed separately. Weaning weight and final feed-test weight were corrected for the age of the calf. Analysis of variance was performed to indicate the effects on birth weight, 180-day corrected weaning weight, final feed test weight, and average daily gain on test.

Years had a highly significant effect on all traits studied. Lines produced a significant effect on birth weight in heifer and bull calves and 180-day corrected weaning weight in the heifer calves. Age of dam showed a depressing effect on weaning weight from younger cows, but the reverse was evident in postweaning gain, which indicated a compensatory effect in the postweaning environment for the preweaning environment.

Years x lines was used as the only estimate of sire effect in these one sire lines, realizing this estimate was confounded. This effect was most evident in the postweaning daily gains in both heifer and bull calves. Inbreeding of dam indicated a positive effect on birth weight, but a negative effect on weaning weight. Bull calves were depressed significantly by inbreeding of dam. This depression may be due to the bulls having a greater growth potential, retarding them more than the heifers by the decreased milk supply. Inbreeding of calf did not have any significant influence on productive traits studied, but partial regressions of weight on inbreeding of calf were negative. Regressions of weight on weaning age indicated heifer calves born early in the calving season are retarded in their preweaning gains when compared to those born later in the calving season. This was not the case with the bull calves.

Mature weight was affected by inbreeding of the dam when the weight was taken after a period of stress such as calving and early lactation period. Maturity of the dams was estimated to be reached at six years of age in the three inbred lines studied.

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ABSTRACT

The influence of years, lines, age of dam, years x lines, inbreeding of dam, inbreeding of calf, and weaning age, on performance traits in three closed lines of Hereford cattle was studied. Data were collected over a 14-year period at the North Montana Branch Experiment Station. Records from dams of three closed lines and their subsequent calf production were included in a least squares analysis. Heifer and bull calves were analyzed separately. Weaning weight and final feed-test weight were corrected for the age of the calf. Analysis of variance was performed to indicate the effects on birth weight, 180-day corrected weaning weight, final feed test weight, and average daily gain on test.

Years had a highly significant effect on all traits studied. Lines produced a significant effect on birth weight in heifer and bull calves and 180-day corrected weaning weight in the heifer calves. Age of dam showed a depressing effect on weaning weight from younger cows, but the reverse was evident in postweaning gain, which indicated a compensatory effect in the postweaning environment for the preweaning environment. Years x lines was used as the only estimate of sire effect in these one sire lines, realizing this estimate was confounded. This effect was most evident in the postweaning daily gains in both heifer and bull calves. Inbreeding of dam indicated a positive effect on birth weight, but a negative effect on weaning weight. Bull calves were depressed significantly by inbreeding of dam. This depression may be due to the bulls having a greater growth potential, retarding them more than the heifers by the decreased milk supply. Inbreeding of calf did not have any significant influence on productive traits studied, but partial regressions of weight on inbreeding of calf were negative. Regressions of weight on weaning age indicated heifer calves born early in the calving season are retarded in their preweaning gains when compared to those born later in the calving season. This was not the case with the bull calves.

Mature weight was affected by inbreeding of the dam when the weight was taken after a period of stress such as calving and early lactation period. Maturity of the dams was estimated to be reached at six years of age in the three inbred lines studied.

INTRODUCTION

In recent years concern and emphasis has been placed on improving production of livestock through the use of closed lines. Improvement of productive traits of beef cattle is slow due to long generation interval and single births. Research in plant and animal breeding has been directed toward development of inbred lines and subsequent testing of these lines for combining ability in an effort to speed improvement.

In evaluating differences among individual animals within a beef cattle herd, it is helpful to know what environmental and genetic factors might be affecting growth and performance of animals. Some factors known to affect the production of Hereford cows are years, lines, age of dam, season and interactions of these factors.

A least squares analysis was used to indicate the extent to which these factors affected production and what effect, if any, inbreeding of dam and progeny have on production over a period of time.

This study was conducted at the North Montana Branch Experiment Station employing 14 years of data from three closed lines of Hereford cattle.

REVIEW OF LITERATURE

There are many variables that affect the production of livestock. The following will be reviewed for their effect on production in different environments and using different types of analyses: (a) years, (b) lines, (c) age of dam, (d) inbreeding of dam, (e) inbreeding of calf, (f) sire, (g) weaning age, (h) sex, (i) selection intensity, and (j) adjustment factors.

Years

Years appear to show as significant effect on production as any factor reviewed. Stonaker (1958) stated that differences between years had significant effects on weights and gains in traits studied. A significant year effect on production traits was also found by Alexander and Bogart (1961), Busch et al. (1962), Flower et al. (1963), and Gottlieb et al. (1962). Marchello (1960), using 26 years of data from the North Montana Branch Experiment Station, found a significant year effect on birth and weaning weights. Pahnish et al. (1964) found year effects were significant at the one percent level of probability on weaning weight and fall yearling weight but not on birth weight. Harwin et al. (1965) concluded that equations for the year x age of dam interaction term should be included in the model to obtain unbiased estimates of various effects as they influence weaning weight.

Lines

Flower et al. (1963) using North Montana Branch Experiment Station data reported that line effects were highly significant for birth weight, weaning weight, and postweaning daily gains in the heifers where both line cross and inbred lines were included. This agrees with Stonaker (1958) in the considerable variation observed in performance of different inbred lines and their crosses. Flower et al. (1963) also observed there was no significant difference in postweaning gain when the three inbred lines of bulls were analyzed.

Age of Dam

Age of dam effect on production varies, but most data analyzed does reveal a significant effect (Bailey and Gilbert, 1962; Burgess et al., 1954; Knapp et al., 1942b; Godbey and Godley, 1961; Harwin et al., 1965; Marlow and Gains, 1957; Stonaker, 1958). Harwin (1964) concluded that the age of dam continued to exert a substantial effect on yearling weight. Weights of cows of 2½ years and 3½ years were heavier for dry cows than cows nursing calves.

Flower et al. (1963) found a highly significant effect of age of dam on birth weight, weaning weight and postweaning gains in the heifers. Birth weight increased with increased age of dam to 6 years while weaning weight increased with age of dam through 7 years. This agrees with Koch and Clark (1955) who found that the age of dam had a marked influence on all traits studied except fall yearling score. The cow's production with regard to birth weight, weaning weight, and weaning score increased steadily from 3 to 6 years of age followed by a decline in production.

Knapp et al. (1942b) found age of dam affected weaning weight in a curvilinear manner. His data indicated an increase in weaning weight up to 7 years of age followed by a slight decrease after 8 years of age.

Urick (1958) found that the 2-, 3-, and 4-year-old cows at the North Montana Branch Experiment Station, Havre, Montana, weaned calves below the average of mature cows by 39, 22, and 8 pounds, respectively, grouping cows from 5 to 10 years of age as mature. These differences were highly significant statistically.

Pahnish et al. (1964) found age of dam effects on weights of bulls at birth, weaning time, after a period of stress, and at fall yearling age were important, ($P < .05$) to $P < .01$). These effects on all heifers traits were nonsignificant.

Inbreeding of the Dam

Inbreeding of the dam affects two major factors, (1) production, and (2) mature weight of dam.

Production of the dam

Davenport et al. (1965) found a marked effect on calf crop due to inbreeding of dam when all ages of cows were studied. Removal of data from 2-year-old cows resulted in no significant differences. This is consistent with evidence that inbreeding effects are more pronounced in younger animals.

Burns (1964) analyzed the data on 1,015 beef calves at the Fort Robinson Beef Cattle Research Station, Crawford, Nebraska and the Agricultural Experiment Station, Lincoln, Nebraska. He found the average inbreeding of dam at these stations to be 0.10 and 0.04, respectively. Curvilinear inbreeding effects on several traits were detected; however, results were not consistant from class to class within a trait or between biologically similar traits. In each case of curvilinear depression, the rate of decrease became smaller with each increment in inbreeding. This suggests that the true effect of inbreeding may follow a negative exponential or decay type curve as indicated when the data were plotted.

Foote et al. (1959) reported on 536 gestations in 258 Holstein cows and 6 different sire lines. The average inbreeding of the dam was 24.7 percent. Inbreeding of the dam displayed no significant effect on the birth weight or gestation length.

Sutherland and Lush (1962) found that after 25 years of mild inbreeding, birth weight decreased with increased inbreeding of dam by approximately 0.2 pounds for each percent of inbreeding. This is in agreement with Noland et al. (1964) who studied the effects of inbreeding in a Poland China line of swine on certain productivity traits. As the inbreeding of the dam increased, there was a significant decline in pig birth weight with the greatest decline being from the dams of 40 to 50 percent inbreeding. Also, as the inbreeding of the dam increased there was a slight, but significant, reduction in weaning weight. This effect was largest in the pigs produced by dams with 40 to 50 percent inbreeding. Inbreeding of the litter had a larger effect on pig weaning weight than did inbreeding of the dam.

Brinks et al. (1965) reported that inbreeding of the dam had a more detrimental effect on preweaning gain, weaning weight, and weaning score of bulls than heifers. Bulls, having a greater growth potential, are probably retarded more than heifers by the decreased milk supply of their mothers than by the increased inbreeding of the dam. These data showed that inbreeding of the dam had a negligible effect on birth weight because partial regressions for both sexes were slightly positive. The female population showed some compensation during the postweaning period for the small effect of inbreeding of the dam.

McCleery and Blackwell (1954) discovered the effect of inbreeding of the dam on calf weaning weight to be a positive partial regression of 0.95 pounds per 1 percent inbreeding of the dam. This is contrary to the findings of Koch (1951) who found for each 1 percent inbreeding of the dam a decrease in weaning weight of -2.54 pounds. Burgess _et al_. (1954) also reported a negative regression of -1.15 pounds for each 1 percent inbreeding of the dam.

In studying the effect of inbreeding of dams on feed-test gains of their calves, Alexander and Bogart (1961) found significant results. More highly inbred cows produced calves that gained more rapidly. These authors felt that the suckling and the postweaning periods are, in part, under different genetic control. The depression in suckling rate of gain was not due to the milk supply because inbreeding of the dam did not depress suckling gain. Bogart (1965) also reported that the inbreeding of the dam did not significantly influence any of the traits measured except rate of gain on test, which showed a positive relationship with inbreeding during this portion of the study.

Swiger _et al_. (1961), using data from the Nebraska Agriculture Experiment Station, Lincoln, showed that inbreeding of the dam had a negative effect on growth rate and feed consumption at -0.005 pounds ± 0.0030 and -0.0170 pounds ± 0.0107, respectively.

Mature weight of the cow

Brinks _et al_. (1962a) used data collected during the years 1926 to 1959 at the U. S. Range Livestock Research Station to obtain mature weight estimates. The data indicated that cows continue to add weight until eight years of age. This is in agreement with Knox and Koger (1945) in that the greatest weights of range cows were obtained at 6 to 8 years of age. Younger cows tended to grow more during the winter months than older cows. Cows gained from spring until fall and until nearing maturity at 5 years of age. Spring weights, however, included nearly a full term calf.

According to Hillers and Freeman (1964), the intra-sire regression of weight on inbreeding per one percent inbreeding was -0.3 at birth, -0.7 at six months, -1.5 at one year, -1.9 at two years, -1.4 at three years, -4.5 at four years, and -3.2 at five years. This finding was in a closed Guernsey herd with an average inbreeding of 6.4 percent.

Harwin (1964) reported the effect of inbreeding appeared to diminish with increasing age up to 2½ years. Bartlett and Morgolin (1944) found cattle can be inbred 20 percent without reducing frame size but beyond the 20 percent level of inbreeding, some undesirable recessive factors may show up.

Sutherland and Lush (1962) found the effects of inbreeding were maximum at 3 years of age and tended to diminish at later ages. Inbreds grew more slowly at early ages and more rapidly at later ages. Nelson and Lush (1950) also reported the shape of the growth curve changes as intensity of the inbreeding changes. Inbreeding slows early growth, but permits growth to continue longer. Thus, mature size will not be decreased and may be increased.

Inbreeding of the Calf

Much of the literature shows inbreeding of the calf affects (1) birth weight, (2) weaning weight, and (3) postweaning performance. In general, inbreeding of calf and dam had a marked effect in depressing birth and weaning traits according to Brinks et al. (1965). Inbreeding of the calf had a more pronounced effect on females than on males. This is indicated by partial regressions on inbreeding over three times as large for females for birth weight, preweaning gain and weaning weight. Inbreeding of calf also had a sizable detrimental effect on postweaning gain and final off-test weight among the pre-selected bull population. This inbreeding effect of the calf was greater as age increased to 18-month weight in both actual and standard units of measure.

Birth weight

Theurer et al. (1965) using a chi-square analysis found that inbreeding of the calf caused a highly significant difference in calf losses. However, when each sex was analyzed separately, females were more adversely affected by increased inbreeding levels than males. Inbreeding level caused a highly significant difference among female losses, but no significant difference among male losses. Similar results were found by Bradford et al. (1958) in swine. The Wisconsin Agriculture Experiment Station data indicated that an increase of 10 percent in litter inbreeding would result in a decrease of approximately 0.20 pigs farrowed per litter. In individual pig weights they found a change of -1.1 pound in 56-day weight and -5.1 pound change in 5-month weight for each 10 percent inbreeding of pig.

Nelson and Lush (1950) reported a decrease of 1/8 pound in birth weight of Holstein-Friesian calves for each 1 percent increase in inbreeding. Sutherland and Lush (1962), reporting on 25 years of mild inbreeding data on Holstein-Friesian cattle, found birth weight decreased with increased inbreeding of both calf and dam by approximately 0.2 pounds for each percent of inbreeding.

According to Foote et al. (1959), the inbreeding of the calf had a significant effect on birth weight but not on gestation length. This study was conducted on 536 gestations in 258 Holstein cows with the average inbreeding of calf being 24.9 percent. The standard partial regression of birth weight on inbreeding of the calf was negative and statistically significant.

Conversely, Alexander and Bogart (1959, 1961) studied the relative effects of selection and inbreeding in 280 calves in four inbred lines and found no effect of inbreeding on birth weight. They were unable to explain the lack of influence on birth weight. This is in agreement with Bovard et al. (1963).

Godbey and Godley (1961) studied 659 Berkshire pigs with an inbreeding range of 0 to 56 percent. Analysis of variance indicated that inbreeding had a highly significant effect on weight and body measurements taken at birth and at 56 days of age. As inbreeding increased, the weights and measurements decreased, but effects of inbreeding leveled off and tended to remain constant for those pigs with coefficients of inbreeding above 20 percent.

Weaning weight

McCleery and Blackwell (1954) studied the effect of mild inbreeding on weaning weight and grade of range calves. Estimates of effects of inbreeding of calf on weaning weight varied somewhat in the three analyses used.

When sires and the inbreeding of the dam were ignored, the pooled intra-year partial regression was -0.74 pounds per 1 percent inbreeding of the calf. When the estimate was obtained within sires and years and ignoring inbreeding of the dam, the partial regression was -0.63 pounds per 1 percent inbreeding. When years and inbreeding of the dam were controlled statistically, the effect of inbreeding of the calf was -1.19 pounds per unit of inbreeding. These estimates showed that inbreeding depresses weaning weight of range beef cattle. In agreement with these findings Koch (1951) reported the inbreeding of the calf depressed weaning weight -0.48 pounds for each percent inbreeding, and Burgess et al. (1954) reported regression of -1.76 pounds for each unit of inbreeding of the calf.

Bogart (1965) reported a significant negative effect of inbreeding of the calf on suckling gains. The depressing effect of inbreeding increased the age of calves when they reached 500 pounds and 800 pounds body weight. Postweaning rate of gain showed an increase followed by a plateau, and a decline as the inbreeding increased from 0 to 30 percent.

Postweaning performance

Hoornbeek (1965) investigated the selection program for performance in one inbred Angus and three inbred Hereford lines of cattle. Performance increased early in the inbreeding program, then leveled off and subsequently declined. Generally favorable response in the Angus line resulted from a lower initial performance, a broader genetic base, and having more animals from which to select. Data from repeat matings showed that more variability in performance existed during the preweaning than in the postweaning period. Zero and low levels of inbreeding were associated with a high preweaning performance and low postweaning performance, respectively. At higher levels of inbreeding, the reverse was true.

Stonaker (1954) observed that calves from inbred lines had lower feedlot gains and utilized feed less efficiently than outbred calves. This result is similar to that found by Swiger et al. (1961) in which the inbreeding of the calf depressed 168-day average daily gain and feed consumption, -0.0075 $\pm$ 0.0036 pounds and -0.0208 $\pm$ 0.0137 pounds, respectively.

Winters et al. (1943) reported that rate of gain between weaning and the 200 pound weight in inbred swine decreased at an average of 0.0035 pounds daily for males and 0.0029 pounds for females per unit increase in inbreeding.

Alexander and Bogart (1959) found no effect of inbreeding in cattle on rate and economy of gains while on performance test. This was believed to be a compensation effect of selection for the expected inbreeding depression.

Rollins et al. (1949) studied the effect of inbreeding on growth from birth to 56 months of age. The average inbreeding was 15 percent with a range from 0 to 47 percent. The maximum effect occurred at 6 months of age where an increase of 1 percent inbreeding caused a decrease of 0.47 percent in mean weight and, at 4½ years of age, a decrease of 0.10 percent in mean weight. Inbreeding appeared to affect the prenatal and postnatal rate of growth. Inbred animals were smaller at birth and grew more slowly to about six months of age than did outcrossed animals. Between the sixth and twelfth month of age inbreds began to grow more rapidly than outcrosses and continued to do so for the remainder of the period studied.

Sire Effects

Knapp and Phillips (1942a) found a significant difference between sires in weaning weight but there was no significant difference between sexes of calves by the same sire. In 1940 the data showed one sire producing heifers weighing 27 pounds more than male calves at weaning. There was a significant difference between sires and a significant sex x sire interaction.

Knapp et al. (1942b) also indicated a significant sire effect on birth weight as well as a significant effect on weaning weight. This is in agreement with Pahnish et al. (1961) who found sires to have a significant influence on the weaning weight of both bull ($P < .05$) and heifer calves ($P < .01$).

Tallis et al. (1959) found a large line x year interaction that he thought might be due to sampling error.

Weaning Age

Weaning age reflects the effect of season of birth or date of birth with respect to other calves being studied when all are weaned at a fixed date. Flower et al. (1963) stated that date of birth had a highly significant effect on birth weight, although a partial regression of -0.0533 per day would not amount to large adjustments because of relatively small differences in dates of birth. Partial regression of 0.1614 pound per day would indicate that older calves gained at a somewhat faster preweaning rate than younger calves. The partial regression of postweaning daily gain on weaning age was small and nonsignificant, although the regression tended to be slightly negative.

Marlow and Gains (1957) found age of calf to be of little influence on the preweaning gain up to 240 days of age but there was a greater influence on type score. Season of birth was an important source of variation in both traits measured when the four seasons were compared as follows: December 16 - March 15, March 16 - May 31, June 1 - August 31, and September 1 - December 15.

Knapp et al. (1942b) reported in an analysis of weaning weight that age at weaning had a significant effect. This is in agreement with Burgess et al. (1954).

Bailey and Gilbert (1962) studied the factors affecting performance traits of Hereford cattle. Initial age was an important source of variation ($P<.01$). This variation affected initial weight, final weight, and conformation score under range conditions.

Sex Differences

It is well recognized by most researchers that sex differences will influence weights and gains of livestock.

Birth weight

Koch et al. (1959) evaluated the influence of sex on birth weight in beef cattle using 1,434 bulls and 1,512 heifers. Bull calves averaged 5.2 pounds or 1.076 times heavier than heifer calves at birth. This is in agreement with Koch and Clark (1955) who stated male calves were 5.6 pounds heavier at birth than female calves.

Knapp (1942b) also found a significant difference between sexes at birth, and was confirmed by Tallis et al. (1959) with 5.3 pounds, Flower et al. (1963) with 5.2 pounds, and Foote et al. (1959) with a difference of

5.92 pounds in favor of the male calves while being gestated 1.44 days longer than females.

Weaning weight

According to Flower et al. (1963) bull calves were 28 pounds heavier at weaning than heifers. If 180-day corrected weaning weight was used the difference was 24.1 pounds. This is similar to Koch and Clark's (1955) findings of 26.2 pounds heavier for the bulls than heifers.

Pahnish et al. (1961) reported bull calves being significantly heavier than heifers ($P < .01$) in a study of two ranches. On one ranch the weaning weight difference between sexes ranged from 44 to 99 pounds for a period from 1949 to 1954. On the second ranch sex differences ranged from 53 to 77 pounds for a period from 1952 to 1954. Significant sex differences in weaning weight were also reported by Bovard et al. (1963), Burgess et al. (1954), Koch, (1951), Marchello, (1960), Marlow and Gains, (1957), and Stonaker, (1958).

Knapp and Phillips (1942a) in studying the superiority of a bull in progeny tests advised that both sexes of his offspring be included. Their study indicated that in postweaning gains some sires apparently produce better gaining heifers than steers or better gaining steers than heifers.

Theories of sex differences

Stonaker (1962, 1963) stated that heterosis in weaning weight of female Hereford calves was 15 percent, whereas in males heterosis showed 8 percent. This 50 percent increase in heterosis of the females over the males was thought to be due to the extra sex chromosome. Thus, in this species the greatest heterosis is in the homogametic sex. It is suggested by Stonaker (1962) that the expected contribution to heterosis from the sex chromosomes be called homogametic heterosis.

Theurer et al. (1965) supported this theory. However, when only calves of two-year-old dams were considered, there was actually a negative heterosis for males. When calves from two- and three-year-old dams were excluded, no homogametic heterosis for viability was observed. They suggest the homogametic heterosis needs to be studied in the light of possible natural selection against large line-cross male calves at birth. If such a situation prevails, the extra heterosis of the female would be an artifact associated with age of dam.

Brinks et al. (1963) stated that observed differences are essentially the same genotypes which show a differential response in an environment that is actually different for the two sexes in proportion to their potential for growth during the preweaning period. Carter and Kincaid (1959) have discussed this in regard to heritability differences they obtained between sexes for weight at six months. It was pointed out earlier that bull calves were affected more by increased inbreeding of dam, presumably through decreased milk production.

Brinks et al. (1963) further state the effect of maternal environment and additional preweaning environmental conditions could mask the response to inbreeding of male calves and also explain the lower heritability estimates obtained on male calves. If this is true, the magnitude of differential sex response in weaning traits to inbreeding, heterosis, and estimates of heritability would depend on the level of environment to which the calves were subjected.

In analyzing year and age of dam effects, Pahnish (1964) suggests that growing bulls are possibly more sensitive or responsive to certain environmental changes than growing heifers.

Harwin (1964) found estimates of the line per mating system effect to indicate substantially greater heterosis in heifer calves. Increased heterosis in heifer calves was not associated with a corresponding increased inbreeding depression which suggested the possible involvement of environmental factors.

Selection Intensity

The level of production in inbred lines will vary considerably between the traits, but some of this variability can be explained in terms of amount of selection applied.

Brinks et al. (1965) found that selection pressure for increased weights, gains, and body scores were fairly intense for the sire with 18 percent of the bulls maintained for use in breeding herds. Selection practiced among females was less intense but was consistently positive except for gain from weaning to 12 months (first winter period) and for mature weight.

According to Flower et al. (1964) selection pressure was much greater in the male sex, with bulls used averaging about one standard deviation above the mean of the unselected population. In general, lines in which selection was most intense showed the greatest estimated genetic progress.

Hornbeek (1965) stated that automatic selection against inbreeding occurred on the sire side in conjunction with selection for increased performance. Due to the low selection intensity for females, selection was for increased inbreeding among females.

Stonaker (1951) reported on a herd that was closed for over 20 years. The average inbreeding was about 30 percent. This herd was intermediate in size and showed considerable phenotypic uniformity.

Gregory (1961) stated that most economic traits decline with inbreeding. Fertility and mothering ability are traits which seem to show the greatest decline with increased intensity of inbreeding. Bulls from production-selected lines consistently did well but it was not known what proportion of the advantage was due to selection practiced in these lines. Since increased performance would seem to be due to the additive gene effects, the most logical inference is that these results were largely the effects of selection in these lines. Rather high heritabilities (additive genetic variance) for most economically important traits indicated that heterosis (non-additive genetic variance) may not be as important in beef cattle as has been shown in some other species.

Alexander and Bogart (1961) stated it was in the highly heritable traits that inbreeding depression was not in excess of the selection effect. This is in agreement with Nelson and Lush (1950) who reported that selection can be used to counterbalance the inbreeding effect. Dickerson et al. (1954) evaluated selection in developing inbred lines of swine. They concluded that selection would favor the less inbred pigs and their dams.

McBride (1965) concluded that an animal breeder should have a wide sample of high merit genetic material in developing foundation stock. Careful consideration should also be given to environmental conditions under which animals are measured for selection.

Adjustments and Correction Factors

Birth weight

Because birth weight is largely under the influence of maternal environment, it is reasonable to assume that factors affecting birth weight are less important than those affecting later weights. It is known that age of cow at the time the calf was born, calf sex, and gestation length have a large influence on weight at birth.

Dawson et al. (1947) found male calves averaging 4.2 pounds heavier than female calves in a herd of Shorthorn cattle. However, the greatest effect on birth weight in this study was due to age of dam.

Burris and Blunn (1952) found male calves averaged 5.3, 4.5, and 4.9 pounds heavier than heifers, respectively, in Angus, Hereford, and Shorthorn herds. Differences between years were not significant statistically. These workers found 10 percent of the sex differences was due to differences in gestation length.

According to Knapp (1942b) calves from 2-year-old cows were about 10 pounds lighter at birth than calves from mature cows. Changes in age of cow had little effect on birth weight after four years of age.

Koch and Clark (1955) found calves from 3-, 4-, and 5-year-old cows to weight 5, 2, and 1 pound less at birth, respectively, than calves from cows 6 to 10 years of age. The difference between 6 and 10 years in age of dam was found to have little effect on the calves.

Dawson et al. (1947) found gestation periods for male calves to average 281.6 days and 280.7 days for the female calves. It was concluded by the authors that males tend to be heavier at birth than females.

Weaning weight

Urick (1958) found growth of calves from 140 days to 220 days of age to be linear in a study conducted at the North Montana Branch Experiment Station. For each day increase in age, calves gained 2.03 pounds.

Johnson and Dinkel (1951) studied monthly weights of 297 beef calves to calculate correction factors for adjusting weaning weights of range calves to a standard age. One set of linear correction factors was developed to adjust weights taken between 120 and 155 days to a standard age of 155 days. Two sets of factors were developed for the period from 155 to 225 days of age which corrected weights to the standard age of 190 days.

Botkin and Whatley (1953) adjusted weaning weights of calves to a standard age of 210 days. The formulae used in this adjustment are as follows:

$$\text{Age intercept} = \text{Average age} - \frac{\text{Average weaning weight}}{\text{Regression coefficient}}$$

$$\text{Corrected weight} = \text{Actual weight} \times \frac{\text{Standard age} - \text{Age intercept}}{\text{Actual age} - \text{Age intercept}}$$

Ages of calves used in this study varied from 210 to 260 days. In using this method, it was assumed that growth was linear during that portion of the growth curve to which corrections were applied.

Harwin *et al.* (1965) recommended the use of the regression of the calf's own preweaning daily gain to adjust for age-of-calf effects. According to Gottlieb *et al.* (1962) regression coefficients of weaning weight on weaning age were 1.79 and 1.21 pounds in two lines under study.

When combining data from different herds, Koch *et al.* (1959) found that a multiplicative factor based on the ratio of mean daily gains was considered most effective.

Final weight

Brinks *et al.* (1962b) found the regression of final weight on age of calf to be 1.89 pounds, which is similar to the average preweaning daily gain of 1.94 pounds.

When correcting for 18-month weight, Marchello (1960) used a constant of 13 pounds per week in deviation from the average age of the group. This value was obtained by determining the regression of weight on age when the weight was taken.

EXPERIMENTAL CONDITIONS

General

Data for the present study were collected at the North Montana Branch Experiment Station, Havre, Montana on the performance of three closed lines of Hereford cattle. These lines are designated as Havre lines 1, 2, and 3. The first calves from line 1 were born in 1948, and the first calves from line 2 and line 3 were born in 1949 and 1950, respectively. This study includes 14 years of weights and scores of these cattle through 1963.

Inbreeding of the Cattle

Inbreeding was calculated for each animal within each of the three lines by a computer program developed by Yates (1965) using the principles developed by Wright (1922) and Emik and Terrill (1949). The average inbreeding of dams and calves are shown as follows: for line 1, 9.45% and 13.44%; line 2, 6.50% and 13.69%; and line 3, 5.56% and 15.85%. Inbreeding of the dams ranged from zero percent to 41.2 percent.

Range Conditions

The early spring and late fall range is located at the North Montana Branch Experiment Station, seven miles southwest of Havre. This range consists largely of native and introduced grasses with a large portion being crested wheat (*Agropyron desertorum*), needle and thread (*Stipa comata*), and blue gramma (*Bouteloua gracilis*).

During the summer grazing period the cattle graze on the Rocky Boy Indian Reservation mountain lease located 30 miles south of Havre in the Bearpaw mountains. As described in the "Annual Grazing Report" from the North Montana Experiment Station, the mountain range vegetation consists largely of grasses such as Timothy (*Phleum pratense*), June grass (*Koelaria* cristata), Idaho fescue (Festuca idahoensis), Rough fescue (Festuca scubrella), and Mountain brome (Bromus marginatus). The grazing and stocking rates are regulated by the United States Forest Service personnel. The grasses are about six inches in height before the cattle are turned in the pastures.

Weather Conditions

Extreme temperatures occur in the Havre area in summer and winter. The United States Weather Bureau office at Havre has recorded wide extremes with an absolute minimum of -57 degrees Fahrenheit, and an absolute maximum of 108 degrees Fahrenheit during the last 74 years. The station has 47 years of weather information with almost equal extremes. The warming effect of the winter Chinook winds often cause a violent fluctuation in temperature. An 80 degree rise was once reported in a single hour.

The average annual precipitation reported at the station is 11.51 inches with about one-third of this occuring during the months of May and June. Sixty-five percent of the total moisture occurs during the spring and summer growing periods of April through September. Generally the snowfall at the station is light, with six inches of snow on the ground being the deepest cover most of the years. Chinook winds are common and tend to reduce the snow cover.

Climatic conditions at the mountain summer grazing pasture differ greatly from those at the station. Approximately five to seven more inches of precipitation are recorded during the months of June, July, and August than at the station with the temperature being five to ten degrees cooler. Thus, we can say the grazing conditions are much better on the summer range than at the station, in terms of benefit to the animal.

EXPERIMENTAL METHODS AND PROCEDURES

General

The data from the three closed lines contained records of 290 bull calves and 360 heifer calves along with information on their dams. Data for the bull calves were analyzed separately from the heifer calves due to the large sex differences.

Dams were divided into eight groups according to age with two groups containing the records of the three-year-olds. Group one contained two-year-olds with their first calf; group two contained three-year-olds with their first calf; group three contained three-year-olds with their second calf; group four contained four-year-olds; group five contained five-year-olds; group six included six and seven-year-olds; group seven included eight and nine-year-olds, and group eight included cows ten years and older.

Weight and Scores

Birth weights were taken within six hours after the calves were born. Calves were ear-tagged and tattoed for identification when weighed. Calves retained as replacements were branded with a hot iron for permanent identification. The identification system consisted of three digits, one of which identified the year the animal was born.

Weaning weights and weaning scores were taken between the first and fifteenth of October at the mountain lease with the calves then being trucked to the main station and put in dry lots.

Calves were weighed on test a few days after weaning and the initial weight on test was an average of weights taken on three successive days. Final weight or weight off test was also taken using weights taken on three successive days. The test period for the bulls was 168 days, and for the heifers it was 140 days.

Dams were weighed three times during a year: first was final winter weight taken prior to calving at about March 1; next weigh date was approximately June 1 when the cows were taken to the mountains; final weigh date ranged between October 1 and November 1, depending on weather conditions, when the cows were brought down from the mountains.

Managing the Breeding Herd

Winter feeding starts in December at the Havre station during most years. In earlier years of the project, the winter ration for the cows consisted of about 50 percent cereal straws and about 50 percent legume and grass hay fed daily. The cows were fed approximately the amount of roughage they would eat, which approximated 20 pounds per head. The hay portion of the ration was gradually increased through the gestation period with a corresponding decrease in straw, so at the beginning of the calving period the ration was mainly legume and grass hay.

In the later years the legume and grass hay part of the ration was replaced by corn silage. Corn silage was decreased prior to calving with hay being increased.

Heifers calving for the first time were wintered separately from the older cows, and fed a ration consisting of grain, hay, and alfalfa in earlier years with corn silage being their main source of roughage in later years. Their daily allowance amounted to 17-20 pounds per head of dry matter. Thus the heifers were in better condition by calving time than the older cows.

Following calving, the cows and heifers were grazed on crested wheat pastures from the middle of April through May. The cows were trailed to the mountain lease to be lotted into their respective breeding herds in early June. The bulls were with the cows for a 60-day breeding period at which time the bulls were removed and the cows were combined into one herd. The cows then grazed the mountain pasture until approximately November 1, when they were trailed to the Havre Station for the winter period.

Selection of the Breeding Stock

One of the breeding projects at the Havre Station involved testing the three closed lines of purebred Hereford cattle by mating them to an unrelated fourth line of high quality Hereford grade cattle (tester line). This tester line of cattle consisted mainly of the Miles City line 1 cattle. Every two years a high producing bull, as measured by the performance of his progeny, was selected at the Miles City Station to be used as the sire of the tester line of cattle called Havre line 4. The general purpose of this project was to study the specific combining ability of the three purebred lines.

Another phase of the project was to study the general combining ability of the three purebred lines. This involves mating young bulls from the purebred lines to commercial cattle and comparing their offspring with offspring from commercial sires of the area.

Very little selection was practiced on heifer calves because during the experiment the great majority of the heifer calves were needed to increase the line numbers and furnish replacement stock. However, some culling occurred at 18 months based on weaning weight, 140-day test gain index, and 18-month weight.

Most of the selection was placed on the linebred bulls with a system of sequential culling being practiced. Such culling was done at weaning, at the end of the feed test, and upon completion of the progeny test. Approximately 80-90 percent of the male progeny were left intact and placed on feed. Castrations were performed for reasons of slow pre-weaning growth, conformation defects, or color pattern. Bull calves were individually fed for 168 days, and mass selection was practiced on weaning weight and feed lot gains as indicated by yearling weight. Whenever possible, two high-gaining yearling bulls from each of the three purebred lines were test-mated to cows of the grade tester line. These breeding groups, with approximately 15-20 cows each, were assigned at random within age groups. Also, approximately one-third of the cows of the tester line were assigned to bulls of their own line to furnish replacements. At the conclusion of the progeny test, the line bulls which performed best with respect to their crossline progenies' weights, gain, and carcass merit were selected as possible herd sires. They were used only if their crossline progeny were superior to the current herd sire's progeny. When yearling bulls were used in test-cross matings, they became available to the line matings as 3- or 4-year-olds, but often there was not complete information on a bull until he was five years old.

The ration for the feed test of the bulls was a concentrate feed consisting of 35 parts rolled barley, 35 parts dried molasses beet pulp, 20 parts rolled oats, and 10 parts wheat bran. Roughage was alfalfa hay, with each bull being fed according to appetite. Bulls were individually fed in a barn.

The heifers' 140-day feed test ration was good quality second cutting alfalfa hay with 2 pounds of rolled barley added to the ration in latter years. The heifers were group fed in an outside lot with good protection from the weather.

Method of Analysis

All of the bull and heifer calves used in the analyses were from the three closed lines. Due to the sex difference that has been reported by Eckles (1919) and McCandlish (1922) in early work, and by Urick (1958) and Marchello (1960) in the Havre data, the bull and heifer calves were analyzed separately. All data were analyzed by the method of least squares analysis as described by Harvey (1960). The independent variables used in the analysis were years, lines, age of dam, and years x lines with partial regression of weights and gains on inbreeding of dam, inbreeding of calf, and weaning age. The dependent variables studied were birth weight, 180-day corrected weaning weight, final weight on feed test, and average daily gain on feed test.

RESULTS AND DISCUSSION

Birth Weight

There was a highly significant difference ($P < .01$) in birth weight among years, lines and age of dam in heifer calves, while bull calves showed a highly significant difference ($P < .01$) among lines, age of dam, and inbreeding of dam, and a significant difference ($P < .05$) among years. This is presented in Table I. The mean birth weight of the heifer calves and bull calves is given in Table II.

TABLE I. MEAN SQUARES FOR BIRTH WEIGHT.

Factor	Heifers		Bulls	
	d.f.	Mean square	d.f.	Mean square
Years	13	140.9**	13	134.9*
Lines	2	928.2**	2	408.6**
Age of dam	7	709.8**	7	398.5**
Years x Lines	26	76.6	26	113.7*
Inbreeding of dam	1	124.9	1	654.0**
Inbreeding of calf	1	30.8	1	2.9
Weaning age	1	0.4	1	7.5
Error	308	55.4	238	73.2

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

The year x line interaction was included in the model to remove the sire effects in the analysis. This would lead to greater accuracy in estimating the other parameters. It cannot be used to reach conclusions with respect to sire effects *per se* since such would be confounded.

Partial regression coefficients shown in Table III were nonsignificant except for birth weight of bull calves on inbreeding of their dams. This was a positive value of 0.371 pounds for each percent inbreeding. This would indicate that selection pressure exceeded the depressing effect, if there was any, that was due to the inbreeding of the dam. The effect of inbreeding of an animal was of less magnitude as the animal reached matur-

TABLE II. UNADJUSTED MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION BY SEXES FOR BIRTH WEIGHT.

		Heifers				Bulls			
Factor		No.	Mean	S.D.	C.V.	No.	Mean	S.D.	C.V.
Sex		397	73.0	9.93	13.60%	351	79.0	11.00	13.92%
Line	1	135	70.0	10.87	15.53	116	76.9	11.23	14.60
	2	154	75.3	9.72	12.91	133	81.9	9.65	11.78
	3	108	73.6	7.86	10.68	102	77.8	11.68	15.01
Age of Dam	2	60	63.6	10.58	16.64	23	71.1	7.47	10.51
	3[a]	37	72.0	8.08	11.22	52	74.8	11.10	14.84
	3[b]	30	71.6	8.88	12.40	16	74.1	10.03	13.54
	4	81	75.0	7.71	10.28	63	78.2	9.61	12.29
	5	52	76.1	7.77	10.21	61	79.5	11.71	14.73
	6-7	78	77.0	10.47	13.60	79	83.6	10.81	12.93
	8-9	52	73.6	8.73	11.86	45	83.4	9.52	11.41
	10+	7	72.0	5.16	7.17	12	74.6	7.87	10.55
Years	1950	11	72.9	5.84	8.01	25	76.3	9.81	12.86
	1951	36	74.4	7.22	9.70	26	78.1	8.80	11.27
	1952	31	73.4	7.42	10.11	31	82.4	7.81	9.48
	1953	22	78.5	13.59	17.31	27	86.6	10.76	12.42
	1954	32	71.3	8.76	12.29	30	81.5	10.22	12.54
	1955	32	73.4	10.07	13.72	15	86.0	9.06	10.53
	1956	18	72.9	7.19	9.86	18	76.7	16.57	21.60
	1957	26	72.3	7.95	11.00	26	76.2	8.33	10.93
	1958	29	70.6	7.52	10.65	19	75.6	10.89	14.40
	1959	30	68.1	9.55	14.02	14	72.1	6.95	9.64
	1960	32	76.4	9.78	12.80	20	75.6	15.33	20.28
	1961	29	76.4	12.53	16.40	21	84.0	9.97	11.87
	1962	29	72.6	7.80	10.74	25	77.8	10.17	13.07
	1963	29	71.6	8.03	11.22	32	79.0	10.91	13.81

[a] three-year-olds with first calf
[b] three-year-olds with second calf