PHENOTYPIC MATERNAL CORRELATIONS AND THE EFFECT OF SELECTION AND CROSSBREEDING IN COMMERCIAL COW HERDS

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ABSTRACT

PHENOTYPIC MATERNAL CORRELATIONS AND THE EFFECT OF
SELECTION AND CROSSBREEDING IN COMMERCIAL COW HERDS

By

Charles Arthur McPeake

Records from the Lake City Breeding Project were analyzed to evaluate cow-progeny relationships, cow production, feedlot performance and economics. The project included four breeding groups of fifty cows each: group 1, unselected Herefords; group 2, Herefords selected for yearling weight; group 3, a rotational cross with Hereford, Angus, and Charolais; and group 4, a rotational cross with Hereford, Angus and Holstein-Fresian. Female selection within all groups except 1 was based upon yearling weight. Randomly selected bulls from breeding group 1 were used as sires in group 1. Sires used in other groups were selected on yearling weight from AI studs and Michigan State University purebred herds.

Dam-progeny relationships primarily consisting of weaning growth traits were determined using simple correlations within years to obtain phenotypic maternal correlations among groups. More negative than positive correlations within the crossbred groups revealed that additional milk received by the nursing crossbred heifers may have impaired their cow productivity. Weaning grade correlations were low but positive for the crossbred groups.

All differences among groups for several production traits at weaning were highly significant unless specifically designated otherwise. The highest percent calves weaned of cows saved was 89.7 for group 4 and the lowest was 79.7 for group 2 with a significance of ($P < .05$) among groups. Adjusted weaning weights were 185, 206, 233 and 250 kg for groups 1 to 4, respectively. Weaning conformation scores were close to low choice (12) for all groups. They ranged from 11.9 for group 1 and 4 to 12.2 for group 2. The fall weight of cows in groups 3 and 4 was near 450 while it was 423 and 396 kg for groups 2 and 1, respectively.

Within groups 3 and 4, weaning comparisons were made between matings with the exotic breed (Charolais in 3 and Holstein-Fresian in 4) as the sire with the British breed as the maternal grandsire and a British breed as the sire with the exotic breed as the maternal grandsire. Within groups 3 and 4, British sired calves were heavier than exotic sired calves in 205-day adjusted weight.

After weaning the steer calves were transported to East Lansing where half of each breeding group received a ration of corn silage and 1% body weight of corn for the 1972 steers. The 1973 steers were fed a ration of 40% corn silage and 60% high moisture corn. The 1974 and 1975 steers were fed two rations with half of each breeding group per ration. The rations were corn silage plus protein supplement and 60% high moisture corn, 40% corn silage plus protein supplement. All steers within a nutritional treatment level were slaughtered in a commercial packing house on a given day of the year, the day that

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80% were estimated to be in the choice grade. Differences in final weight ranged from 455 kg for group 1 to 559 kg for group 4. Values for average daily gain were 0.93, 1.07, 1.05, and 1.05 kg for groups 1 to 4, respectively. Percent cutability ranged from 48.3 for group 2 to 50.0 for group 1. Crossbred steers had a higher marbling score than the Herefords selected for yearling weight (13.3 vs. 11.5). Breeding group 1 steers had the lowest retail yeild per day of age with 0.40 kg, while group 3 had the highest with 0.48 kg.

An economic analysis was conducted to estimate the relative ranking in dollar return over out-of-pocket cost for the four cow herds within the project. The cost and production analyses were attained by working backward from carcass values adjusted for equal body fat composition and postweaning feedlot cost of gain. Cow dry matter intake was adjusted for weight, selection, and in groups 3 and 4, the additional calf weaning weight. For return to the beef herd over out-of-pocket cost, group 2 had a 50.9% advantage over group 1, while the crossbred groups had a 7.4% advantage over group 2.

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By

Charles Arthur McPeake

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INTRODUCTION

With the beef producers' ever-increasing cost of production, the industry must identify the important factors involved in an efficient mating system for beef cattle production and the most accurate means of selection for production efficiency.

Much emphasis has been placed on developing crossbreeding systems incorporating dairy and exotic breeds as one method of meeting part of the goal of more efficient beef production.

We know that utilizing hybrid vigor as a tool for improving production efficiency is a one-time proposition, and without proper selection in both the crossbred and purebred populations the chances of additional improvement are small, if existent.

Major genetic changes within any commercial system are dependent on the selection practiced in the bull-producing herds. However, it is necessary to know the factors within the cow herd that influence efficient calf production and interrelationships among these factors. Boston et al. (1975) had this to say as an introduction to phenotypic relationships within Angus and Hereford females: "The accuracy of a heifer's weaning and yearling weights as indicators of her subsequent cow productivity depends on the degree of the phenotypic relationships between these weights and the weaning weights of her calves. Several beef cattle studies have suggested if a heifer grows

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too fast and/or becomes too fat because of her preweaning environment (such as heavy milking dam), her milk producing ability as measured by her calves' weaning weights will be impaired (Koch and Clark, 1955; Christian et al., 1965; Mangus and Brinks, 1971; Kress and Burfening, 1972). If this phenotypic antagonism exists, it is important to evaluate its relative importance in conventional populations of cattle under normal conditions."

Hopefully, with correlation analyses of these relationships, we can obtain the most accurate tool, or tools, in selecting young females for maximum cow productivity and efficiency.

The total beef production system cannot profit by concentrating on cow-calf performance alone. As Gregory (1965) stated: "One segment of the beef cattle industry cannot be divorced from the other segments. From a long-term standpoint, there is an interdependence among them. The commercial producer is interested in cows with a long productive life that wean a high percentage of heavy, high grading calves; the feeder desires rapid and efficient feedlot gains; and the packer and retailer are interested in the maximum amount of edible portion per unit of live or carcass weight. The consumer expects this edible portion to be tender, flavorful and juicy."

Beef cattle scientists and producers need more information dealing with the total system of beef production; that is, conception to consumer. They each need this information to effectively formulate breeding plans that will yield optimum production and yet be the most efficient system of selecting and mating animals.

To an extent, the amount of harvest a producer reaps from selection alone is largely dependent upon the heritability of a selected trait; thus, heritability is an important parameter in animal breeding. Lush (1948) states its importance as follows: "A characteristic is not inherited as such. The thing inherited is the ability to respond in a given manner to a given environmental circumstance. The observed phenotype is the net result of these inherited potentialities and the environmental circumstances, such as nutrient supply, temperature, diseases, accidents, etc. which they encounter. Between the genes which are transmitted and the observed phenotype of the plant or animal is a considerable gulf of time and of chemical and physiological processes in which the genes interact with environmental substances, forces and conditions, and also with the primary and secondary products of each other. The complete story of all that happens in this period includes the whole subject matter of embryology and the physiology of growth and development." Gregory (1961) reported that heritabilities for most of the economically important traits, except fertility, seem high enough for selection to be reasonably effective.

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LITERATURE REVIEW

Phenotypic Maternal Correlations

Many effects are responsible for a heifer's weaning weight and her subsequent ability to produce. Information found in the literature was limited both for the number of breeds and crossbreeding that studied phenotypic maternal correlations.

Heritability of maternal effects for weaning weight was estimated as 15, 46, 50, and 34% by Deese and Koger (1967), Hill (1965), Hohenboken and Brinks (1971), and Koch and Clark (1955b), respectively. The average was 36%.

Koch (1972) concluded that genetic and permanent environmental components of maternal ability and covariance of individual and maternal effects accounted for 35 to 45% of variation in daily gain from birth to weaning.

Swanson (1967), working with dairy cattle, summarized that forcing rapid growth to achieve early calving is not an economical practice and cannot be expected to improve lactation efficiency.

Swanson and Spann (1954) fed identical twin Jersey heifers two different rations until breeding age, one a fattening ration with the other being normal. Milk production results indicated that excess fattening during growth is detrimental to lactating ability.

Davis and Willett (1938) found the correlation between rate of gain of Holstein heifers and their lactation milk fat yield to be insignificant.

In contrast to most other researchers, Johansson (1964) concluded that live weight of heifers at 6, 12, 18, and 24 months of age had little value for the prediction of future milk yield.

Holty et al. (1961) found that rate of gain was negatively correlated with lactation yield of Jerseys and positively correlated in Holsteins and Guernseys.

Data from beef herds relating levels of rearing to milk production of cows are limited. Totusek (1968) compared weaning weights of calves out of heifers reared under different systems, e.g. (1) weaned at 140 days of age; (2) weaned at 240 days of age; and (3) creep fed and weaned at 240 days of age. Heifers weaned at 140 days of age produced calves that weighed about 10 kg more than those out of creep fed heifers.

Christian et al. (1965) reported weaning weights of twin Hereford heifers were correlated negatively with measures of their milk production.

Plum and Harris (1968) compared milk production from Holstein heifers reared by suckling their dams with heifer mates reared under normal dairy calf management. Milk production from heifers that suckled their dams was only 74% as much as that from heifers reared under usual dairy calf management conditions.

Gould and Whiteman (1975) studied phenotypic correlation coefficients between the 70-day weight of the dams and the 70-day weights of their lambs. They found the phenotypic correlation coefficients when the dams were 15, 24, 36, 48, 60, 72, 84, and 96 months old were -.13, -.01, -.07, .00, .05, .01, .16, and .28, respectively. They stated that the change in correlation coefficients for -.13 for lambs from 15 month-old dams to .28 for 96 month-old dams suggested a possible negative relationship between ewe lamb nutrition and subsequent maternal influence that disappears as the ewe gets older.

Koch and Clark (1955a) compared the theoretical composition of paternal and maternal half-sib correlations, the correlations between offspring and dam, and offspring and sire with observed values to estimate the influence of maternal environment. The results suggested that maternal environment from conception to birth and from birth to weaning had a large influence on birth weight, gain from birth to weaning, and weaning score.

Underfeeding heifers was detrimental in some cases to the first lactation, but in later lactations subnormally reared heifers equalled or exceeded milk production from normally reared heifers (Crichton et al., 1960; Hansson, 1956; Swanson, 1960; Swanson and Hinton, 1964; Thomas et al, 1959; also see reviews by Schultz, 1969; Swanson, 1967).

Brinks et al. (1964) found from data on 1,608 cows raised at the United States Range Livestock Experiment Station, Miles City, Montana, that the phenotypic correlation of the most probable producing ability based on calf's adjusted weaning weight with dam weaning weight and l

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and 18-month weight were 0.09 and 0.20, respectively. Eighteen-month weight was the best single predictor of producing ability.

Mangus and Brinks (1969) studied environmental and genetic factors affecting cow productivity in 22 years of data from inbred and linecross Hereford cattle. Their results indicated that environmental factors reflecting high preweaning levels of nutrition had a detrimental effect upon subsequent cow productivity.

Mangus and Brinks (1971) concluded from data obtained at the San Juan Basin Branch of the Colorado Experiment Station that it is evident a detrimental effect upon subsequent cow productivity does exist from higher levels of nutrition during the preweaning growth period of the beef heifer and that relatively low levels of preweaning nutrition resulted in higher cow productivity values. The authors also concluded that the low correlation between the heifer's weaning weight and her subsequent productivity indicates that the heifer's weaning weight is a poor criterion for selection to increase cow productivity.

Koch (1969) found large regression coefficients that suggested a negative relation between environment affecting dam's growth and maternal environment she provided her offspring.

Vogt and Marlowe (1966) in a study of genetic parameters found results which they believe reflect a negative relationship (genetic or environmental or both) between the dam's weaning performance and the maternal environment she subsequently provides for her offspring.

Koch and Clark (1955b) studied the correlations from data with 4,234 calves and their 1,231 dams for weaning weight, 1,762 calves and their 671 dams for weaning score, and 1,623 calves and their 822 dams for fall yearling weight. The year effect and the age of dam effect were eliminated by grouping pairs of records into subclasses according to the years the cows were born and the years the calves were born.

	TRAITS OF THE DAM		
TRAITS OF THE CALF	Weaning weight	Weaning score	Yearling weight
Weaning weight	.06	.01	.12
Weaning score	.04	.08	.13
Yearling weight	.15	.12	.23

They found correlations for dam-offspring weaning weight, dam-offspring weaning score, and dam yearling weight with calf yearling weight were .06, .01, and .23, respectively.

Marchello et al. (1960) estimated heritability of 18-month weight of heifers and its relationship to weaning weight of their first calf. The data were collected from the Hereford experimental herd at the North Montana Branch Station over 26 years. Their estimate of heritability of 18-month weight of heifers was 0.36. The correlations involving 631 cow-first calf pairs for 18-month weight with calf weaning weight (adjusted for sex and age) was 0.24.

Christian et al. (1965) studied the association of preweaning and postweaning traits with weaning weight in cattle. Their correlations included 88 offspring from 52 cows that were 2, 3, and 4 years old. They estimated the correlation of weaning weight of dam with weaning weight of calf was 0.07. A negative correlation was significant between the weaning weight of the cam and her butterfat production to

60 days of age of her calf. The negative correlations between weaning weight and other measures of milk production approached significance. They suggested a negative genetic or environmental correlation, or both, between weaning performance of the dam and the maternal environment she provides for her calf. If this correlation is genetic, selecting heifers superior in weaning weight would increase genetic value for growth response but decrease milk production.

Effects of Selection and Crossbreeding

Gregory (1972) stated that many of the questions coming from the beef cattle industry to which we are not able to provide an adequate response relate to life cycle production systems--relationships and/or interactions among the biological and/or economic components that affect production costs and value of product, i.e. reproduction rate, milk, growth rate, mature weight, shape of growth curve, efficiency of growth, efficiency of maintenance, life cycle feed efficiency, composition of gain, meat quality, production of greater growth rate in the market animal per unit of cow size maintained by specialized crossbreeding systems, etc. and all of this for the full range of resource situations that we have for the production of beef.

"Appreciation of the practical value of hybrid vigor is as old as the mule, but its scientific investigation began only relatively recently" (Mather, 1955).

Dunn *et al*. (1970) concluded that estimates of the correlation between a sire's genetic ability to produce straightbred and crossbred progeny were high, indicating that mass selection in purebred populations contributing germ plasm to crossbred populations would be approximately as effective in improving commercial crossbred performance as it would be in improving commercial straightbred performance.

Klosterman (1972) concluded there are problems in the beef industry much greater than how big cattle should be. These include feed efficiency, calving percentage, numbers of cattle going to slaughter as a percentage of those maintained, and type as it may be related to carcass grade and composition.

Dam Performance

Willham (1972) had this to say about maternal performance: "The cow can utilize roughage in the creation of the early nutritional environment of her calf. This milk, which provides the early nutrition of the calf, is in part genetically determined. The nutritional environment of the calf is not the only contribution of the cow to her calf. Half the genes of the calf are a sample of those possessed by the cow. Thus, the performance of the calf throughout its lifetime can be considered a series of compound traits, influenced to greater or lesser degrees by the genes of the calf (half having come from the dam) and its own environment and by the genes of the dam and her environment as expressed in the performance of her calf."

Nelms and Stratton (1967) concluded from their study on selection for yearling weight in a closed line of beef cattle that a positive phenotypic change can be achieved with selection in small populations. They added that correlated responses of birth weight, 180-day weight and average daily gain were achieved in selecting for yearling weight.

Urick et al. (1971) from data on cow and calf weights representing Angus, Charolais, and Hereford breeds over four years at the U.S. Range Livestock Experiment Station studied relationship between cow size and calf weaning weights. They found Charolais tended to produce more calf weight for each unit of weight increase in cow weight than Angus or Herefords, but the differences were not significant.

Singh et al. (1970) with records on 619 calves by 13 sires over 6 years found the influence of dam's weight on preweaning average daily gain and adjusted weaning weight was nonsignificant, but heavier cows tended to wean heavier calves.

Pahnish et al. (1969) compared Brown Swiss dams to Angus, Hereford, and Charolais dams and found the average advantage of Brown Swiss for steer and heifer calves, respectively, was 33.6 and 32.5 kg for weaning weight. They also found that dams of the beef breeds showed an average advantage of 2.3 and 1.5 units in weaning score of steer and heifer calves, respectively, over Brown Swiss dams.

Schwulst et al. (1968) studied heterosis in 250 head of straightbred and crossbred cows that included Angus, Hereford, and Shorthorn breeds. Calves were weighed at two weeks, six weeks, and at 200 days of age. They found calves from the crossbred cows weighed 42.3 kg, 61.0 kg, and 197.1 kg and calves from the straightbred cows weighed 40.1 kg, 56.5 kg, and 184.7 kg for the respective weigh times.

Cundiff et al. (1974) in a crossbreeding experiment involving Angus, Hereford, and Shorthorns found that the analyses over all breeds, ages, and systems of management revealed that effects of heterosis reduced ($P < .05$) the interval from parturition to first estrus and the average date of conception. They found that the calf crop weaned was 6.4% greater for crossbred than for straightbred cows ($P < .01$). They added that actual weaning weight per cow exposed was 23 kg or 14.8% greater ($P < .01$) for crossbred cows than straightbred cows. The cumulative effect of individual heterosis and maternal heterosis in this project was 23% on kg of calf weaned per cow in the breeding herd.

Sidwell and Miller (1971a) studied reproductive efficiency of ewes in pure breeds of sheep and their crosses. Fertility, prolificacy, lamb livability and overall reproductive efficiency were generally higher for crossbred than for purebred matings. For fertility, 15 out of 20 crosses showed positive hybrid vigor. Fourteen out of 20 crosses showed positive hybrid vigor for prolificacy. In percent of lambs born alive of total lambs born, 13 crosses showed positive hybrid vigor while for percent of lambs of live lambs born all crosses except one showed superiority over the purebreds. All crosses except three showed considerable improvement over the purebreds for overall reproduction. For percent of lambs weaned of ewes bred, the overall crossbred average was 94.0% compared to 78.8% for the average of the purebreds.

Long and Gregory (1974) estimated heterosis effects observed for birth weight were 3% and for preweaning growth was 8%. No differences between sexes were significant for amount of heterosis.

Brinks et al. (1972) found heterosis estimates for maternal effects on birth weight, preweaning daily gain, 205-day weaning weight and weaning score was: 1.5, 5.4, 4.7, and 0.47.

Rutledge et al. (1971) gave an estimate of repeatability for total milk yield as 0.38. They explained that this value suggests a low to moderate heritability of milk production in beef cows.

Schwulst et al. (1968) studied milk production from 149 crossbred and 101 straightbred cows involved in a heterosis experiment of Hereford, Angus, and Shorthorn cattle. Twelve-hour milk production was measured when calves were two weeks of age, six weeks of age, in June after cows were sent to breeding pastures, and at weaning indicated 1.6, 8.5, 6.8, and 38.0% heterosis for the respective observations.

Cundiff et al. (1974) studied the effects of heterosis on milk production and maternal heterosis on preweaning growth traits and conformation score in reciprocal crossbred and straightbred cows of the Hereford, Angus, and Shorthorn breeds. They found that over all breeds, ages and management regimes, effects of maternal heterosis were 1.7% for birth weight ($P < .05$), 3.6% for weight at 135 days ($P < .01$), 4.7% for weight at 200 days ($P < .01$), and one-sixth of a grade ($P < .01$) for conformation.

Deutscher and Whiteman (1971) studied the productivity as 2-year-olds of 31 Angus-Holstein crossbred heifers compared to 41 grade Angus heifers under range conditions. Their results indicated that crossbreds are capable of producing more milk and heavier weaning calves under range conditions but probably need a higher level of nutrition to rebreed and maintain body weight.

For weaning weight, Neville (1962) reported 66% of the variation in weight at 8 months was due to milk consumption. Drewry et al. (1959) found 60% of the variation in weight at 6 months was due to milk. Totusek et al. (1971) found 2.9, 5.4, and 7.0 kg for average daily milk in Hereford, Hereford-Holstein, and Holstein cows, respectively.

Ewing et al. (1968) reported that energy requirements of mature beef cows were influenced importantly by both weight and levels of milk production.

Rutledge et al. (1971) upon examination of 205-day calf weight revealed significant effects of years, sires, milk production, calving date, calf birth weight, and cow weight whereas effects of age of dam were not significant. On a within herd-sex-year basis, approximately 60% of the variance in 205-day weight could be attributed to the direct influence of the dam's milk yield. They concluded that it appeared that milk quantity rather than milk quality was more important in its influence on 205-day weight.

Weaning Traits

Weaning weight in beef cattle is a complex trait since it reflects not only the growth ability of the calf but also the maternal environment created for the calf by its dam. With this in mind, the traditional 205-day weaning weight is of economic importance to the beef industry and is the logical first step in a performance program.

Koch et al. (1974) studied response to selection in groups of Hereford cattle selected for (1) weaning weight, (2) yearling weight, and (3) index of yearling weight and muscling score. They found an average estimated response, expressed in standard deviation units per generation, in the three lines was: weaning weight, 0.23, 0.17, and 0.15 and yearling weight, 0.36, 0.43, and 0.33, respectively. They concluded that correlated responses to selection in the three lines suggest that a wide variety of selection patterns will lead to improvement in all traits even though optimum selection indexes may maximize improvement in particular traits.

Swiger et al. (1962) concluded that results do indicate that considerable genetic progress can be made in producing beef at a lower cost by selecting for weaning weight and postweaning gain.

Brinks et al. (1967) found from data on 241 bull and 228 heifer calves in line-crossed Hereford cattle at the U.S. Range Livestock Experiment Station, Miles City, Montana, that heterosis for weaning weight and weaning score amounted to 5.1% and 2.5% for bull calves and 9.4% and 2.7% for heifer calves.

Sagebiel et al. (1974) mated Angus, Charolais, and Herefords for straightbred and all possible reciprocal two-breed crosses to study heterosis effects on adjusted 205-day weight and weaning scores. They found that crossbreds were superior to the straightbreds that made up the cross for all traits. They also found the largest amount of

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heterosis for weaning weight was shown by the Angus-Hereford crosses, averaging 5.7%, but this same cross showed no heterosis for weaning score. They concluded that Charolais were significantly superior to Angus and Herefords for weaning weight both as a breed of cow and as a breed of bull, and Angus were slightly superior to Herefords as a breed of cow for weaning weight. For weaning score, Angus were superior to Herefords and Charolais as a breed of cow with no significant differences between breeds of bulls.

Gregory et al. (1965) in an experiment involving 751 calves of the Hereford, Angus, and Shorthorn breeds and all reciprocal crosses among them, found significant heterosis effects on birth weight, average daily gain, weaning weight adjusted to 200 days, and weaning conformation score of 3.8, 4.8, 4.6, and 1.6%, respectively.

Gaines et al. (1966) studied records of 572 straightbred and crossbred matings of Angus, Hereford, and Shorthorn cattle, collected over five years. They explained their most important finding as being a 10% advantage in calves weaned from crossbred matings, indicating heterosis for fertility and livability. They continued that there was evidence of heterosis in birth weight, preweaning growth rate, and weaning weight of 1.8, 2.6, and 3.4%, respectively. Feeder grade at weaning was slightly, but not significantly, lower among crossbred calves.

Rollins et al. (1969) studied the amount of hybrid vigor to be expected from two-way crosses of the Angus, Hereford, and Shorthorn breeds for various traits. They found for weaning weight the two-way cross estimates of hybrid vigor were 7.0 ± 4.8 kg for the Hereford and Angus cross; 10.2 ± 5.3 kg for the Hereford and Shorthorn cross, and 6.5 ± 5.0 kg for the Shorthorn and Angus cross. They also found there was no consistent evidence of hybrid vigor for weaning grade.

Sidwell and Miller (1971b) studied birth weights and weaning weights of lambs in production of some pure breeds of sheep and their crosses. They found increases in body weight due to crossbreeding (hybrid vigor) were more evident in weaning weight and gain from birth to weaning than in birth weight. For weaning weight, 14 out of 20 crosses showed some degree of increase due to heterosis. Fifteen out of 20 crosses showed some degree of heterosis for gain from birth to weaning. For overall averages of all breeds and crosses, the crossbred lambs exceeded the purebred lambs by 0.11 kg in birth weight, 1.3 kg in weaning weight and gain from birth to weaning, and 0.015 kg in average daily gain.

Feedlot Performance

Gregory *et al*. (1966a) studied heterosis effects in the British breeds for a 252-day postweaning feeding period on a growing-fattening ration of approximately 65% total digestible nutrients. They found the heterosis effect on growth rate decreased with increasing age in the three 84-day periods. Thus, the heterosis effect on growth rate was related to age. The heterosis effects on growth rate were not significant during the third 84-day period. The heterosis effects of different measures of feed efficiency were small and were generally not significant.

Long and Gregory (1975a) studied heterosis for postweaning growth and weight in crosses of the Angus and Hereford breeds. The data included over 1,300 calves. They found that differences between effects of the Angus and Hereford breeds on postweaning performance were not statistically significant. Crossbreds exceeded straightbreds by 5 to 6% for postweaning gain and weight; heterosis effects were similar for steers and heifers.

Vogt et al. (1967) concluded from a crossbreeding project involving Angus, Hereford, and Shorthorn cattle, that in general, results indicated that some heterosis in postweaning growth rate and weight (2.1 to 5.2%) can be expected up to about 18 months of age. They found a significant advantage of crossbreds over straightbreds in weight after approximately 18 months of age resulted from the maintenance of a significant advantage at younger ages.

Carcass Characteristics

Hedrick (1972) in a review summarized that the specific size or form of an animal is not as important as the proportions of lean meat produced and its qualitative characteristics. He added the ideal type animal should yield a carcass which in terms of current U.S.D.A. carcass grade standards would have A maturity, a small degree of marbling, grade low choice, and have a yield grade of at least 2 or preferably 1. He continued that the most feasible solution to production of the ideal type appears to be designed breeding and production systems which bypass the undesirable and utilize the desirable traits.

Gregory et al. (1966b) studied the Hereford, Angus, and Shorthorn breeds and all reciprocal crosses among them to evaluate heterosis effects on carcass traits in crosses among these breeds. They found there were significant ($P < .01$) heterosis effects for carcass weight and net merit. The heterosis effect on net merit is of appreciable economic significance. Net merit was computed as the value of the boneless, closely trimmed cuts minus feed costs from weaning to slaughter. Generally, there were significant ($P < .01$) heterosis effects on age-adjusted traits associated with carcass composition. However, when these traits were adjusted for weight, the heterosis effects on composition were negligivle. Thus, the heterosis effects on carcass composition were through heterosis effects on weight at a constant age.

Gaines et al. (1967) studied heterosis of carcass characteristics from crosses among British breeds of beef cattle. They found there was evidence of heterosis in those traits associated directly with growth, namely, carcass weight, area of the l. dorsi and carcass length. Slight indications of heterosis were seen in some of the other traits, but they were not large enough to be of practical importance.

Lasley et al. (1971) in a study of carcass quality characteristics in heifers of reciprocal crosses of the Angus, Charolais, and Hereford breeds found that heterosis effects were negligible among the measures of carcass quality examined.

Urick et al. (1974) analyzed data from 165 steers of Angus, Hereford, and Charolais breeds and the six reciprocal crosses were evaluated to estimate heterosis for various carcass characteristics and palatability scores. In addition, 37 steers from beef times Brown Swiss matings provided evaluations of Brown Swiss influences. Comparisons of crossbreds of the three beef breeds with straightbred showed that heterosis effects were not an important source of variation for carcass quantity and quality traits. Estimates of heterosis were generally low and positive and were significant only for carcass weight per day of age. Steers from Brown Swiss dams and sired by Hereford and Angus sires excelled the straightbred and crossbred beef steers for carcass growth traits and percent cutability.

Vogt et al. (1967) found from a crossbreeding project of Angus, Hereford, and Shorthorn cattle that differences in slaughter grades were generally small, with the significant deviations (in favor of crossbreds) interpreted as a reflection of heavier slaughter weights and presumed higher condition of the crossbreds rather than heterosis in slaughter grade.

Long and Gregory (1975b) estimated heterosis for carcass characteristics from Angus and Hereford crosses. The data included over 1,300 calves. Heterosis was observed for carcass weight, longissimus muscle area and measures of fatness. When they adjusted for hot carcass weight, many of the heterotic effects were removed. Calves that went on feed directly after weaning maintained a degree of heterosis ($P < .05$) for dressing percent, fat thickness, and longissimus muscle area.

Hedrick _et_ _al_. (1975) studied quantitative and qualitative carcass data for 139 short-fed and 148 long-fed steers from a crossbreeding experiment used to estimate the amount of heterosis exhibited by nine different traits. The experiment involved Angus, Charolais, and Hereford breeds and all possible reciprocal two-way breed crosses. They concluded that crossbred long-fed steers were superior to straightbreds by 5.5% in hot carcass weight but were similar for percent retail cuts.

Mason (1966) summarized heterosis studies containing many traits from conception through slaughter.

Production Economics

Lindholm and Stonaker (1957) designed a selection index to attain the maximum genetic progress toward increasing net income per hundredweight of finished product. Price and cost data were applied to 118 Hereford steer calves bred and fed by the Colorado Agricultural Experiment Station, to estimate net income. They found in multiple correlation studies that utilized net income per hundredweight as the dependent variable, indications that weaning weight was the most important trait affecting net income. Other traits considered were weaning grade, daily gain, days to finish, slaughter grade, feed per pound of gain, and 18-month weight of dam.

OBJECTIVES

1. To estimate the relationship of a heifer's growth with her subsequent cow productivity for weaning weight, adjusted weaning weight, and weaning grade in four types of cow herds.
2. To study effects of selection for yearling weight on several traits from conception through slaughter.
3. To study effects of crossbreeding, using either a large exotic or a large dairy breed sire, as a third cross in a three-breed rotational crossbreeding system, on traits from conception through slaughter.
4. To estimate the relative ranking of production economics from conception through slaughter in four types of commercial beef herds.

MATERIALS AND METHODS

Experimental Design

The experimental design consisted of four breeding groups of cattle made up of 50 females each. The cattle in these groups have also been used to evaluate different nutritional and management practices. Thus, the overall experimental design for the project involved a factorial arrangement in which the effects of all the treatments were estimated in an overall analysis. This paper discusses the estimates of the effects of the different breeding groups adjusted for the effects of the different nutritional and management practices that were tested. The numbers of animals studied are shown in Table 1.

Table 2, as presented by Magee and Greathouse (1969, 1970, 1971, 1972, 1973), Magee (1974), and Magee and McPeake (1975, 1976), shows the selection practiced and the mating systems for the different groups.

Group 1 was a control group against which all changes were measured. The replacement bulls used each year were unselected for weight. To do this, the first four bull calves born in group 1 by different sires were retained as sires each year. The following year, these sires were used as clean-up bulls in group 1. After the breeding season ended, semen was collected from each clean-up bull and frozen. The next year this semen was used to inseminate the cows.

Table 1. Total Numbers Within Category Analysis for Cow Age

Category (all age dams)	N
Calves	813
Cows, % weaned	984
Cows, calving ease	919
Cows, weight	1,190
Steers	211
Category (2-year-old dams)	**N**
Calves	145
Cows, % weaned	197
Cows, calving ease	180
Cows, weight	268

Table 2. Breeding Plan for the Different Groups

Breeding Group	Selection	Mating system
1	None	Random
2	Yearling weight	Straightbred
3	Yearling weight	Crossbred[a]
4	Yearling weight	Crossbred[a]

[a]Three breeds of bulls used were Angus, Charolais, and Hereford in group 3; and Angus, Holstein-Fresian, and Hereford in group 4.

In groups 2, 3, and 4, bills were from artificial insemination (A.I.) studs. Michigan Animal Breeders Cooperative (MABC), along with Select Sires, Inc., have been very helpful in furnishing semen for the project. Beef bulls were selected primarily on adjusted yearling weight while the Holstein-Fresian bulls were selected on estimated yearling weight.

In groups 2, 3, and 4, replacement heifers were saved at a rate of 20% each year on the basis of their unadjusted yearling weight. Females in group 1 were saved without consideration of weight, but in the same age groups as heifers in groups 2, 3, and 4. In the fall, the cows were pregnancy tested with 20% being culled to make room for replacement heifers.

Base Population

In 1966, Henry and Edsel Ford donated a herd of Hereford cows to Michigan State University. Of these cows, 200 were selected to represent the base of a breeding project located at the Lake City Experiment Station. The 200 cows were divided into age groups and randomly assorted to four groups of 50 cows each as described in the experimental design.

The first matings of the project were made in 1967 with the F_1 dams producing their first calves in 1970.

Feeding, Weighing, and Management

Cows

Three feeding trials came into effect depending primarily upon the stage of management. The first period was drylot to calving, after the pasture season, with the ration consisting mainly of a combination of grass legume haylage and sudan grass silage. Some years different types of roughage were fed to two groups of cows. Half of each breeding group was assigned to each nutrition group. The length of this period ran approximately from mid-October to mid-January and contained 90 days. The second period began at calving and ended at the start of pasture season; which, on the average, began in mid-January and ended in mid to late May or ranged from 90 to 105 days in length. During this period, the cows received corn silage with the addition of corn and protein supplement depending on cow condition and its projected effect upon their reproductive efficiency. The third and final period was that of pasture. Pastures consisted of both improved and unimproved areas. Time for pasture season was around 165 to 180 days.

Cows were weighed twice per year, at weaning in the fall or more specifically, in early October and again at the beginning of pasture season in mid or late May.

All four breeding groups of cows were maintained together except for the last 45 days of the breeding season when the cows were assigned by breeding group to the designated clean-up bulls.

In the fall, at weaning, each cow was pregnancy checked, treated for lice and grubs, and if 30 months or older tested for brucellosis. Prior to calving the cows were given an annual vitamin A and D injection and an innoculation against leptospirosis, vibriosis, and wormed when necessary as determined by a fecal analysis.

A breeding season of approximately 90 days for cows began the middle of April using artificial insemination for 45 days and another 45 days in which the cows were assigned to their respective clean-up bulls. For the five-year period, several methods to improve heat detection were introduced. The percent of cows that produced AI calves is shown in Appendix Table A1.

Replacement Heifers

At weaning time, the replacement heifers from all groups were grouped and fed together. They received a ration of corn silage and enough grain to insure that reproductive efficiency was not limited by nutritional requirements.

Prior to breeding season, replacement heifers were given a booster immunization against infectious bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD), and parainfluenza (PI_3).

After the first 45 days of breeding season (AI), yearling heifers were grouped with the cows according to their respective clean-up bulls.

Calves

The numbers of calves weaned in this study involved years 1972 through 1976 and are shown in Appendix Table A3.

At birth all calves were tatooed, ear tagged, weighed, and given vitamin shots of A and D and selenium-tecopherol. All male calves except those retained as herd sires in group 1 were castrated and all horned calves dehorned. All calves born in years 1972, 1973, and 1974 were creep fed.

Prior to pasture season, all calves were vaccinated against blackleg and malignant edema. All heifer calves were vaccinated against brucellosis at approximately 6 months of age.

Calves at weaning were weighed and given shots for immunization against infectious bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD), and parainfluenza (PI_3). Steer calves were transported from Lake City to the Beef Cattle Research Center at East Lansing, approximately 150 miles. The 1975 and 1976 heifers not selected as replacements also were shipped to East Lansing. Prior to 1975, heifers not selected as replacements were sold as weanling cattle.

Steers

Steer data for 1972 are from a random half from each of the four breeding groups. This group of steers received a ration of Pro-Sil treated corn silage and 1% body weight of corn. The data for the 1973 steers were again from half the steers. These steers were fed a ration of 40% Pro-Sil treated corn silage and 60% high moisture corn. The 1974 and 1975 steers were fed two rations, each to half the breeding group. The rations were corn silage plus protein supplement and 60% high moisture corn with 40% silage plus protein supplement.

The steers in 1972 did not receive a growth stimulant. The 1973 steers received either a control, Synovex, or Ralgro. Both the 1974 and 1975 steers were implanted initially with diethylstilbestrol.

Intermediate weights were obtained every 28 days after a 16-hour shrink without water.

The 1972 and 1973 steers were fed in outside lots containing no shelter, while the remaining steers were housed in concrete, partially covered, bedded lots.

Slaughter and Carcass Evaluation

Slaughter and carcass evaluation analysis included steers in the 1972 through 1975 calf crops. Steers were slaughtered when an evaluation committee predicted that 80% would grade choice. The steers from the 1972 and 1973 calf crops were slaughtered on September 14, 1973, and August 7, 1974, respectively, according to Magee (1974) and Magee and McPeake (1975). Steers in the 1974 and 1975 calf crops were subjected to two levels of energy, a high grain ration and a high corn silage ration. Steers on the high grain ration were slaughtered according to the criterion for the 1972 and 1973 steers. Then corn silage fed cattle were slaughtered when the mean weight of each group was equal to the mean slaughter weight of the respective group fed high grain. All cattle within an energy level were slaughtered at the same time.

All cattle were transported to a commercial packing plant where they were slaughtered by normal procedures. Hot carcass weights were obtained, and carcasses were chilled for at least 24 hours before they were evaluated. Carcass quality and yield data were collected by a government grader. Michigan State University personnel assisted in obtaining actual rib eye area and external fat measurements.

Economic Analysis Calculations

Several calculations have been made in an attempt to estimate the differences between the four breeding groups for dollar return above out-of-pocket costs. The economic analysis was based primarily on steer average daily gain along with feed efficiency and dry matter intake for the cow depending upon her weight.

Black and Fox (1977) determined that the fairest way to evaluate feedlot performance on cattle of different size and composition was to adjust the groups to an equal body fill and composition basis. For our study this was done using the formulas given in Table 3. In the formula for adjusted postweaning average daily gains, the least squares estimates were used as the basic data. Carcass weight was determined from final weight times the dressing percent of the respective group. The mean dressing percent was 61.71. Days on feed for the four years were calculated by dividing total feedlot gain by least square means for average daily gain.

In the formula for adjusted postweaning feed/gain, again the least squares estimates were used as the basis. Other values were the same as those described for the average daily gain formula. Feed/gain adjustment factor for yield grade was also interpolated from values presented by Black and Fox (1977).

Table 3. Adjustment, Performance, and Carcass Trait Calculations

$$\text{Adjusted Weaning Weight}^{a} = \left[\left(\frac{\text{Actual Weaning Weight} - \text{Birth Weight}}{\text{Days of Age}}\right) \times 205 + \text{Birth Weight}\right]\left(\text{Sex Correction Factor}\right)\left(\text{Age of Dam Correction Factor}\right).$$

$$\%\ \text{Weaned} = \frac{\text{Number of Calves Weaned}}{\text{Number of Cows Saved in Fall}}.$$

$$\text{Average Daily Gain} = \frac{\text{Final Weight} - \text{Initial Weight}}{\text{Days on Feed}}.$$

$$\%\ \text{Cutability}^{b} = 51.34 - \left(5.78 \times \text{Adjusted Fat Thickness, 12th Rib}\right) - \left(0.0093 \times \text{Hot Carcass Weight}\right) - \left(0.462 \times \%\ \text{Kidney, Heart, \& Pelvic Fat}\right) + \left(0.740 \times \text{Ribeye Area}\right).$$

$$\%\ \text{Retail Yield}^{b} = \left[86.6 - \left(\text{Cutability Score} \times 4.6\right)\right] \times .01.$$

$$\text{Retail Kg/Day of Age} = \left(\text{Hot Carcass Weight} \times \%\ \text{Retail Yield}\right)/\text{Days of Age}.$$

$$\text{Adjusted Postweaning Average Daily Gain}^{c} = \frac{\left(\frac{\text{Carcass Weight}}{\text{Mean Dressing Percent}}\right) - \text{Initial Weight}}{\text{Days on Feed}}\left(\text{Average Daily Gain Adjustment Factor for Yield Grade}\right).$$

$$\text{Adjusted Postweaning Feed/Gain}^{c} = \frac{\left(\text{Final Weight} - \text{Initial Weight}\right)\left(\text{Feed/Kg Gain}\right)}{\left(\frac{\text{Carcass Weight}}{\text{Mean Dressing Percent}}\right) - \text{Initial Weight}} \div \left(\text{Feed/Gain Adjustment Factor for Yield Grade}\right).$$

[a] U.S.D.A., 1972.

[b] U.S.D.A., 1973.

[c] Black and Fox (1977).

With the cows in groups 3 and 4 producing more weight of weaned calf, an adjustment for cow dry matter intake was made based on the additional weaning weight of calf over group 2--the straightbred selected group. Starting with least square means for cow weight and calf weaning weight adjusted for age of calf, age of dam, and sex of calf, the ratio of kg calf weaning weight per 100 kg cow weight as presented in data by Klosterman and Parker (1976) and the difference in cow weight expressed as a percent of 100 kg, the necessary calculations were made to determine the extra intake of dry matter by the cow. The calf weaning weight was adjusted for cow weight by taking the difference in kg cow weight as a percent of 100 kg times kg calf per 100 kg cow weight increase plus the weaning weight for group 1. Additional kg weaning weight due to weight were obtained by subtracting weaning weight of group 1 calves from the weaning weight adjusted for cow weight. Additional kg due to selection was determined by subtracting weaning weight adjusted cow weight in group 2 from the least square mean weaning weight in group 2. Weaning weight adjusted for cow weight and selection was figured by adding additional kg weaning weight due to selection and weaning weight adjusted for cow weight. The extra weaning weight used to determine extra cow dry matter was equal to weaning weight adjusted for cow weight and selection subtracted from the weaning weights of groups 3 and 4.

Intake of dry matter by the cow was based on cow weight, lactation, and stage of gestation with regression equations of:

.011 (cow weight, kg) + 6.50 for lactation; .0108 (cow weight, kg) + 1.75 for mid-pregnancy; and .0122 (cow weight, kg) + 2.00 for late-pregnancy (NRC, 1976). Groups 3 and 4 also were adjusted for the extra milk production needed to produce the additional weaning weight over group 2.

Several calculations were made to determine the additional dry matter needed to produce the extra calf weaning weight in groups 3 and 4. With the additional weaning weight available, gain requirement in MCal ME per kg of dry matter and ME content in MCal per kg of dry matter in milk, as presented by NRC (1976), calculations were initiated. Megacalories of metabolizable energy for gain requirement were determined by multiplying additional gain by gain requirement in MCal ME per kg of gain. Kilograms of milk dry matter were figured by dividing total MCal ME requirement for gain by ME content per kg of milk dry matter MCal. Kilograms of milk dry matter divided by percent milk dry matter determined actual kg of milk needed to produce the extra kg of weaning weight. Total requirement for the additional gain in MCal ME was found by multiplying the amount of milk times requirement to produce a kg of milk in MCal ME as presented in NRC (1971). Additional dry matter was determined by dividing the total requirement in MCal ME by MCal ME per kg of grazed Bluegrass as presented by NRC (1976). Additional dry matter needed divided by additional gain yielded the feed efficiency of milk.

Estimates for the four-year period for feedlot heifer average daily gain and feed efficiency were based on feedlot steer information.

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Heifer carcass weight was obtained by multiplying steer carcass weight times 0.82. Average daily gain adjusted for dressing percent and yield grade was found by multiplying steer adjusted average daily gain times a ratio of heifer to steer gain as determined from data presented by Harpster et al. (1977). Feed per kg of gain adjusted for dressing percent and yield grade was calculated by multiplying steer adjusted feed per kg of gain times a ratio of heifer to steer feed efficiency as shown from data presented by Harpster et al. (1977).

Calculations were made to estimate the return from a steer to the cow-calf producer on a per cow unit basis. Steer carcass value was estimated by multiplying carcass weight times carcass value per kg for steers. Feed cost was based on total feedlot dry matter intake times $0.088 per kg with nonfeed costs determined from data presented by Crickenberger and Black (1976). Steer value to a feeder was estimated by taking total feedlot cost from carcass value. Steer value per cow unit was calculated by multiplying value to feeder times percent steer per cow unit (0.5 times percent weaned). Value per kg per cow unit was found by dividing value per cow unit by initial feedlot weight. The return from a heifer to the cow-calf producer based on steer information was calculated in the same manner as the steer estimates.

The return from a cull cow to the cow-calf producer was found by utilizing least square means for cow weight times value per kg times the percent cull cow marketed per cow unit.

The total return to the producer per cow unit if the cow-calf producer finishes his cattle or receives the true worth of feeder calves

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from a 50-cow herd was calculated on steer and heifer value to a feeder plus market value of cull cow. These three sources of income based on percent weaned and culled times their respective value yielded the total return per cow unit.

Out-of-pocket cost per cow unit was dependent upon cow dry matter intake, and breeding group 1 served as a base using the cost of an average cow presented by Fox and Black (1977). Dry matter intake for the cow was adjusted in groups 3 and 4 for the milk production necessary to produce the additional weaning weight. Dry matter intake for replacement heifers and bulls was based on adjusted cow intake with multiplicative factors of .275 and .071, respectively. Cost per kg of dry matter was determined from cost of an average cow presented by Fox and Black (1977) with feed cost for replacement heifers two-tenths of a cent higher than the cow or bull cost suggested by Fox (1977).

The relative dollar return to a cow-calf producer per cow unit combined the steer, heifer, and cull cow value into gross return per cow unit then subtracted out-of-pocket cost to reach the return over and above out-of-pocket cost of production.

Statistical Analysis

The phenotypic maternal correlations were analyzed with a Statistical Package for the Social Sciences (SPSS) program developed by the Vogelback Computing Center of Northwestern University. This SPSS program was implemented with year as the discriminant; thus, it provided simple correlation coefficients on a within year basis.

Performance data for the calf, cow, and steer analysis were analyzed by least squares (Harvey, 1960). For calf performance breeding groups, years, breeding group by year interactions and within BG3 and BG4, a breed of sire effect were used in a model. An identical model was used for analysis of cow performance. For the steer performance breeding groups, years, breeding group by year interactions and treatment groups within years were included in the model.

All statistical analyses were performed on a Control Data Center 6500 computer at the Michigan State University Computer Laboratory.

RESULTS AND DISCUSSION

Phenotypic Maternal Correlations

Correlation estimates of phenotypic relationships between three dam growth traits and two progeny growth traits along with dam weaning grade and progeny weaning grade within years and breeding groups representing types of commercial herds are given in Table 4. Although generally small, especially in the groups that involved selection, 81% of the dam with progeny correlations for growth were positive. Forty-one percent of the positive correlations differed from zero ($P < .05$). Correlations for dam weaning grade (DWG) and progeny weaning grade (PWG) tended to be small and nonsignificant.

Breeding group (BG) 1, unselected straightbred Herefords, had 58% positive significant ($P < .05$) correlations, the highest percentage among groups for dam growth traits. The majority of these correlations were within the 2-year old dams. As age of dam increased, correlations were smaller and nonsignificant, yet most of them remained positive indicating for selection for any dam trait except dam adjusted weaning weight (DAWW) for older dams that a positive response for progeny weaning weight (PWW) and progeny adjusted weaning weight (PAWW) would have been expected. When PWW was adjusted, correlations were smaller, changing heifer growth-cow productivity relationship estimates.

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Table 4. Correlation Coefficients (r) for Measures of Heifer Growth with Measures of Cow Productivity by Breeding Group[a][b]

Calf performance	Breeding group 1 r	2 r	3 r	4 r
	Dam weaning weight			
PWW(2)[c]	.59**	.11	.33*	-.05
PWW(>2)	.16	.02	-.15	.10
PAWW(2)[d]	.46**	.02	.17	-.04
PAWW(>2)	.03	.20*	.07	.38**
	Dam adjusted weaning weight			
PWW(2)	.37**	-.28	.30*	-.01
PWW(>2)	.18	.06	-.05	.12
PAWW(2)	.28*	-.33*	.12	-.05
PAWW(>2)	-.01	.09	.12	.39**
	Dam 18-month weight			
PWW(2)	.61**	.16	.31*	.06
PWW(>2)	.20*	.11	.11	.08
PAWW(2)	.51**	.16	.24	.02
PAWW(>2)	.05	.22*	.27**	.32**
	Dam weaning grade			
PWG(2)[e]	-.03	-.16	.25	.07
PWG(>2)	.06	-.04	.10	.01

[a]Numbers of 2-year old cow-calf pairs within breeding groups 1, 2, 3, and 4 were 50, 39, 55, and 63, respectively.

[b]Numbers of 3-year old and older cow-calf pairs within breeding groups 1, 2, 3, and 4 were 115, 116, 143, and 141, respectively.

[c]Progeny weaning weight.

[d]Progeny adjusted weaning weight.

[e]Progeny weaning grade.

*$P < .05$.

**$P < .01$.

Reports of these relationships for unselected Herefords were not found in the literature. Correlations of DWG with PWG were small being negative for 2-year old dams and positive for the aged dams.

Most phenotypic maternal relationships found in the literature dealt with the Hereford breed. These relationships primarily were subjected to nutritional differences rather than being under normal conditions with breed or selection differences.

Correlations of dam weaning weight with PWW and PAWW for BG2 (the selected Herefords) were small and nonsignificant except for DWW with PAWW for the older dams. A coefficient of .20 ($P < .05$) was estimated for this relationship. This estimate was higher than .06 reported by Koch and Clark (1955b). Relationships based on the three dam growth traits and PWW for older cows indicated selection for any trait in heifer growth should result in phenotypic increases in PWW's. Dam adjusted weaning weight with PWW(2) approached significance with a correlation estimate of -.28. Dam 18-month weight (D 18-MW) was the best single indicator of PWW's. The D 18-MW's correlated with progeny traits were positive and ranged from .11 to .22 ($P < .05$). These estimates agree closely with the same relationship of .12 by Koch and Clark (1955b), .24 ($P < .01$) for PWW with heifer 18-month weight by Marchello et al. (1960).

Dam weaning grade and PWG relationships within BG2 were negative and small with the 2-year old dams having the largest negative estimate.

Phenotypic maternal relationships within a 3-breed rotational cross were found to be nonexistent in the literature. The relationships in this section served as a venture utilizing possibilities of different breeds for crossbreeding and its effect upon phenotypic maternal ability.

Within BG3 or the 3-breed rotational cross involving Hereford, Angus, and Charolais breeds, the phenotypic maternal relationships for the three dam growth traits with PWW were the most consistent indicators for 2-year old dams. The same relationships tended to be lower and even negative for the older dams--D 18-MW with PWW for 2-year old dams had an estimate of .31 ($P < .05$) and PAWW for older dams an estimate of .27 ($P < .01$).

Breeding group 3 relationships involving DWG with PWG were .25 and .10 for 2-year old dams and older dams, respectively. These were the highest positive estimates received for this relationship among groups.

Within BG4, 25% of the relationships were positive and highly significant while 33% were low and negative. For DWW and DAWW with PWW and PAWW, all estimates were low and negative. In contrast to the other breeding groups for D 18-MW, BG4's tended to be lower except for D 18-MW with PAWW for the older dams. Progeny adjusted weaning weight for the older dams was influenced by any of the dam growth traits.

The negative relationships for 2-year old dams in DWW and DAWW possibly could be approached with an explanation of detrimental effects for cow productivity as found by other researchers: Brinks et al. (1964); Christian et al. (1965); Koch (1969); Mangus and Brinks (1971).

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Within BG4, the estimates of the correlations of DWG and PWG were smaller than within BG3; yet they remained positive.

Explanations for the trends and differences are not easy. Several authors have raised questions of the possible existence of a phenotypic antagonism between direct growth and maternal effects for weaning weight. Crossbred dam-offspring relationships tended to have a greater quantity of negative correlations than the straightbred groups. Crossbred dams give more milk than do straightbreds. Hence, the additional milk received by the nursing crossbred heifers possibly could have harmed their cow productivity.

Performance Estimates Among Types of Commercial Herds Using Selection or Selection and Crossbreeding

Calf and Cow Traits

The results of both the calf and cow characteristics were divided into three categories: the analysis for all cow age groups, the 2-year old age group, and certain crosses within breeding groups 3 and 4. These are presented in Tables 5 through 8, respectively.

Weaning Weight

Differences among groups and for specific crosses within groups were significant ($P < .01$). Actual weaning weight (WW) of calves for the selected straightbred Herefords or breeding group 2 (BG2) responded with a 17 kg or 9% increase while data for only the 2-year olds showed a 27 kg or 15% increase over BG1 or the unselected Herefords.

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Table 5. Effect of Breeding Group on Calf Weaning and Cow Performance Within Years

Group	WW** kg	AWW** kg	WWAS[a]** kg	WG[b]**	Cow W[c]** kg	% W[d]*	CE[e]**
1	174	185	192	11.9	396	80.3	1.2
2	191	206	205	12.2	423	79.7	1.5
3	224	233	240	12.1	454	85.1	1.4
4	241	250	259	11.9	453	89.7	1.2

[a]Actual weaning weight adjusted to bull base by multiplying steer and heifer weights by 1.05 and 1.10, respectively.

[b]Weaning grade: 10 = middle good, 11 = high good, 12 = low choice, et cetera.

[c]Cow weight taken at weaning in fall.

[d]Percent weaned represents calves weaned per cow saved.

[e]Calving ease: 1 = little or no help, 2 = hand pull, 3 = chains, light pull, 4 = chains, hard pull, 5 = cesarean.

*$P < .05$.

**$P < .01$.

Table 6. Effect of Breeding Group on Calf Weaning and Cow Performance Within Years for Two-Year Old Dams

Group	WW** kg	AWW** kg	WWAS[a]** kg	WG[b]	Cow W[c]** kg	% W[d]**	CE[e]**
1	158	183	173	11.6	311	71.5	1.7
2	185	221	198	11.9	347	52.9	2.5
3	212	233	226	11.7	381	89.4	2.2
4	250	269	269	11.8	412	79.1	1.7

[a]Actual weaning weight adjusted to bull base by multiplying steer and heifer weights by 1.05 and 1.10, respectively.

[b]Weaning grade: 10 = middle good, 11 = high good, 12 = low choice, et cetera.

[c]Cow weight taken at weaning in fall.

[d]Percent weaned represents calves weaned per cow saved.

[e]Calving ease: 1 = little or no help, 2 = hand pull, 3 = chains, light pull, 4 = chains, hard pull, 5 = cesarean.

**$P < .01$.

Table 7. Effect of Type of Cross on Calf Weaning and Cow Performance Within Years for Breeding Group 3

BOS on BOGS	WW** kg	AWW** kg	WWAS[a]** kg	WG[b]**	Cow W[c]** kg	% W[d]**	CE[e]**
CXB	233	230	250	12.2	450	95.4	1.2
BXC	215	236	230	12.1	459	74.8	1.5

[a]Actual weaning weight adjusted to bull base by multiplying steer and heifer weights by 1.05 and 1.10, respectively.

[b]Weaning grade: 10 = middle good, 11 = high good, 12 = low good, et cetera.

[c]Cow weight taken at weaning in fall.

[d]Percent weaned represents calves weaned per cow saved.

[e]Calving ease: 1 = little or no help, 2 = hand pull, 3 = chains, light pull, 4 = chains, hard pull, 5 = cesarean.

$^{**}P < .01$.

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Table 8. Effect of Type of Cross on Calf Weaning and Cow Performance Within Years for Breeding Group 4

BOS on BOGS	WW** kg	AWW** kg	WWAS[a]** kg	WG[b]**	Cow W[c] kg	% W[d]	CE[e]**
HXB	239	236	256	11.6	450	85.6	1.4
BXH	244	264	263	12.2	455	93.8	1.0

[a]Actual weaning weight adjusted to bull base by multiplying steer and heifer weights by 1.05 and 1.10, respectively.

[b]Weaning grade: 10 = middle good, 11 = high good, 12 = low choice, et cetera.

[c]Cow weight taken at weaning in fall.

[d]Percent weaned represents calves weaned per cow saved.

[e]Calving ease: 1 = little or no help, 2 = hand pull, 3 = chains, light pull, 4 = chains, hard pull, 5 = cesarean.

**$P < .01$.

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Breeding group 3 or the 3-breed rotational cross involving Hereford, Angus, and Charolais increased 33 kg or 15% and 67 kg or 13% for the pooled cow age groups and for the 2-year old dams.

The combining effect of the three breeds in BG4 and heterosis from all crosses was 50 kg or 21% and 65 kg or 26% for the all cow age groups and the 2-year old dams, over BG2. In both BG3 and 4, the weaning weights were larger than BG2's due to the introduction of a larger breed, and in BG4 in addition to size a breed that was developed for milk production. Within BG3, WW favored the calves sired by Charolais bulls out of British cross cows by 18 kg or 8% while in contrast within BG4, calves were 5 kg or 2% heavier sired by British bulls out of Holstein cross dams. The latter was understandable due to the amount of milk produced by Holstein-Fresian crossed dams. This agrees with Cundiff et al. (1974), that actual weaning weight per cow exposed was 14.8% greater ($P < .01$) for crossbred cows than straightbred cows. They also found the cumulative effect of individual heterosis and maternal heterosis in this project was 23% on weight of calf weaned per cow in the breeding herd which agrees closely with BG3 and BG4 results. Deutscher and Whitman (1971) found that 2-year old Angus-Holstein heifers were capable of producing more milk and heavier weaning calves under range conditions but probably need a higher level of nutrition to rebreed and maintain body weight. Mason (1966) summarized studies using the three British breeds and showed that advantages of BG crossbreeding ranged from -3% to 10%.

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Adjusted Weaning Weight

Calf adjusted weaning weight (AWW) for both dam age groups and type of cross within BG3 and BG4 were significant ($P < .01$). The relative ranking of breeding groups from low to high for BG1 through BG4 did not change from the unadjusted data for either of the dam age groups although the calves in BG2 did receive the largest adjustment in both dam age groups. Most of the weaning weight data in the literature were adjusted data as shown by Cundiff et al. (1974), Mason (1966), Boston et al. (1975), and Brinks et al. (1972). The difference for AWW within BG3 favored the British sired calves out of Charolais cross dams by 6 kg ($P < .01$). This may be due to the larger adjustment received by younger age dams in this type cross as compared to the other calves being out of British cross, older dams. In BG4 the calves out of Holstein cross dams were heavier by 8 kg ($P < .01$) and followed the same trend as shown for WW.

Weaning Weight Adjusted for Sex

When weaning weight was adjusted only for sex, again the differences for the four groups were significant ($P < .01$). The effects of adjusting for sex were basically the same in all age dams, 2-year old dams, and the specific cross within BG4 as for AWW. Within BG3 the difference was reversed and given as 20 kg ($P < .01$) in favor of the Charolais sired calves out of British cross dams.

Weaning Grade

Differences between breeding groups for weaning grade (WG) ranged only from 11.9 for BG1 and BG4 to 12.2 for BG2 and were significant ($P < .01$). Calves in all breeding groups for all ages of dams were close to low choice. These results agreed with Gaines et al. (1966). They found differences less for crossbreds, but they were nonsignificant. Sagebiel (1974) found no heterosis effects for weaning grade. Weaning grade differences among breeding groups were nonsignificant; they ranged from 11.6 to 11.9 for BG1 and BG2. Rollins et al. (1969) found no consistent evidence of heterosis for WG. Cundiff et al. (1974) estimated one-sixth of a grade difference between crossbreds and straightbreds.

Charolais sired calves were .1 ($P < .01$) higher in WG than British sired calves out of Charolais cross dams. Both types of cross within BG3 were low choice. The effect of type of cross within BG4 was evident and in favor of British sired calves out of Holstein cross dams by .6 ($P < .01$). This difference was in favor of calves carrying 25% Holstein breed genes versus calves with 50% Holstein breed genes. Pahnish et al. (1969) found a difference of .8 for WG in favor of calves out of beef dams as opposed to Brown Swiss dams.

Cow Weight

Cow weights differed significantly ($P < .01$) among breeding groups for both the all age dams and 2-year old dams. Selection for yearling weight increased cow weight by 27 kg, and crossbreeding that utilized a larger breed increased cow weight 3 kg to 30 kg over the straightbred selected group in BG3 and BG4. For the 2-year old dams, differences were larger. Selection added 36 kg while crossbreeding effects and adding a larger size breed into the rotational crosses accounted for from 34 kg to 65 kg for BG3 and BG4. Specific crosses within BG3 and BG4 did not differ significantly while averaging a little over 450 kg for the four types of crosses. Urick et al. (1971) from data on cow and calf weights compared the Hereford, Angus, and Charolais breeds. They found Charolais tended to produce more calf weight for each unit increase in cow weight than Angus or Herefords although differences were not significant. Singh et al. (1970) found that heavier cows tended to wean heavier calves.

Fertility

Fertility defined as percent calves weaned of cows saved was significant ($P < .05$) among breeding groups for all age cows and ranged from 79.7% to 89.7% for BG2 and BG4, respectively. The 2-year-old dams fertility ($P < .01$) among breeding groups ranged from 52.9% for BG2 to 89.4% for BG3. Within BG3 a difference of 20.4% ($P < .01$) was shown for the specific crosses with the advantage being for the British cross cows bred to Charolais bulls. Within BG4 the specific crosses showed a difference of 8.2% in favor of Holstein cross dams bred to British breed bulls. This difference was nonsignificant. Mason (1966), in a summary of the different studies, found the advantage of crossbreeding for calves weaned as a percentage of cows mated ranged from 1 to 25. Cundiff et al. (1974) found a 6.4% advantage for the crossbred dams.

Sidwell and Miller (1971a) reported a 15.2% difference in favor of crossbred ewes. Percent AI sired calves that were not analyzed statistically, but are shown in Appendix Table A1.

Calving Ease

The subjective score for calving ease was significant ($P < .01$) for the four categories of dams. For all age dams, BG1 and BG4 were low with a score of 1.2 while BG2 was high with 1.5. Again for the 2-year old dam category, BG1 and BG4 were low with 1.7 while BG2 was high with 2.5 score. The Charolais sired dams mated to British sires had .3 ($P < .01$) more calving difficulty than British cross cows bred to Charolais bulls. The effect of type of cross within BG4 favored the Holstein sired females bred to British bulls by .4 ($P < .01$). The results of calving ease found in the literature are limited and did not have the same score descriptions as were used in these analyses.

Feedlot and Carcass Traits

Effects of breeding group adjusted for years for seven of the eight characteristics of steers were found to be significant ($P < .01$) as presented in Table 9. For initial weight (IW) selection in BG2 accounted for 21 kg increase. The three-breed-crosses on the average had a 45 kg increase over the selected Herefords or BG2 for IW. Final weight had the same relative ranking with differences between comparisons becoming more pronounced. The selected Herefords or BG2 had the highest average daily gain with 1.07 kg, BG3 and BG4 had 1.05 kg, and BG1 the lowest with .93 kg. Expected gains for crossbreds are at least

Table 9. Effect of Breeding Group on Feedlot and Carcass Traits for Steers within Years

Table 9. Effect of Breeding Group on Feedlot and Carcass Traits for Steers Within Years

Group	IW** kg	FW** kg	ADG[a]** kg	MAR[b]**	QC[c]*	% CUT[d]**	% RET[e]**	RET yield[f]** per day of age kg
1	187	455	0.93	11.5	11.8	50.0	73.1	0.40
2	208	517	1.07	11.5	11.8	48.3	69.7	0.44
3	249	552	1.05	12.8	12.3	49.3	71.9	0.48
4	257	559	1.05	13.8	12.4	48.5	70.2	0.46

[a]Average daily gain is final feedlot weight minus actual weaning weight divided by number of days.

[b]Marbling score: slight = 7, 8, 9; small = 10, 11, 12, et cetera.

[c]Quality grade: good = 9, 10, 11, et cetera.

[d]Percent cutability is estimated trimmed retail meat using the USDA prediction formula.

[e]Percent retail yield is estimated retail meat based on USDA predictions.

[f]Retail yield/day of age is hot carcass weight times percent retail yield divided by days of age.

*$P < .05$.

**$P < .01$.

the average of breeds making up the cross, but BG3 and BG4 fell below the selected straightbred Herefords. Several researchers have presented results that heterosis effects did exist for postweaning growth, weight, and carcass weight. Vogt et al. (1967) stated that heterosis in post-weaning growth was 2.1% and 5.1% in weight up to 18 months of age. Gregory et al. (1966a) found that the heterosis effect on growth rate decreased with increasing age. Long and Gregory (1975a) revealed that crossbreds exceeded straightbreds by 5 to 6% for postweaning gain and weight. Postweaning average daily gain (ADC) for steers in this study were in contrast to values given in the literature. Marbling score was 11.5, 11.5, 12.8, and 13.8 for BG1 through BG4. Heterosis effects were not thought to make the differences, but rather the average of breeds making the cross. Several carcass traits were influenced by heterosis but not enough to be practically important. Carcass quality grade (QG) was 11.8 for both BG1 and BG2, with 12.3 and 12.4 for BG3 and BG4, respectively as determined by USDA grading standards prior to 1976. Percent cutability as directed by fatness revealed the higher cutability for BG1 of 50% and BG3 the second highest with 49.3%. Breeding group 2 and BG4 were close with 48.3% and 48.5%. For the USDA prediction formula percent retail cuts, relative ranking was the same as percent cutability. For retail yield per day of age, selection indicated a 9% increase for BG2 over BG1. Breeding group 3 yielded the highest amount of retail yield with .48 kg/day, or an 8.4% advantage over BG2, the selected straightbred Herefords. Advantage of BG4 over BG2 was 4.4%. These yields were understandable since day of age for all practical purposes were constant. No comparisons of retail yield could be related directly to this study.

Production Economics

In withstanding today's economic stresses, the cow-calf producer and feeder must know the factors affecting cost of production and marketing of feeder and slaughter cattle. Ultimately, differences in feedlot performance and carcass value are reflected in prices paid for feeder cattle.

As discussed in a prior section, a study was initiated to estimate the relative ranking in dollar return for four types of commercial beef cow herds. The cost and production analyses were attained by working backward from steer carcass values and postweaning feedlot cost of gain.

When steer average daily gain (ADG) was adjusted to equal body fat composition, the ranking of breeding groups as shown in Table 10 did not change from least square mean rankings. Adjustments were necessary as most cattle feeders tend to market slaughter cattle at a uniform degree of fatness. Breeding group 2 (BG2) remained the highest with 1.12 kg while BG1 stayed unchanged with 0.93 kg. The adjustments to equal composition for feed/gain decreased values for BG2 through BG4. Breeding group 1 increased a small amount. Breeding group 2 was one unit below any of the other groups. This indicates that we need to market these animals when they are of equal composition in order to realize these differences. If the BG2 through BG4 cattle

Table 10. Postweaning Performance Adjusted to Equal Dressing Percentage and Carcass Fat

Group	Steer initial and weaning weight	Steer slaughter weight	Dressing %	CW[a] kg	Adj.[b] sla. wt kg	Unadj. ADG kg	Days on feed	ADG[d] adj. Dress % kg	Unadj. feed/ gain	Total[e] Feed kg	kg Feed/[f] kg gain adj. dress %	Yield grade	ADG[g] adj. factor	ADG[h] adj.	Feed/[i] gain adj. factor	kg Feed/[j] kg gain adj.
1	187	455	61.43	279	453	0.93	286	0.93	7.64	2,045	7.69	3.00	1.003	0.93	0.992	7.75
2	208	517	62.08	321	520	1.07	288	1.08	7.38	2,276	7.30	3.75	0.964	1.12	1.079	6.77
3	249	552	62.15	343	556	1.05	288	1.07	8.23	2,490	8.12	3.30	0.989	1.08	1.031	7.88
4	257	559	61.18	342	554	1.05	287	1.03	8.26	2,495	8.40	3.66	0.968	1.07	1.071	7.84

[a]Slaughter weigh times dressing percent.

[b]Carcass weight divided by overall mean dressing percent of 61.71.

[c]Slaughter weight minus initial weight divided by average daily gain.

[d]Adjusted slaughter weight minus initial weight divided by days on feed.

[e]Slaughter weight minus initial weight times feed/kg gain.

[f]Total feed divided by adjusted slaughter weight minus initial weight.

[g]Interpolated from ADG adjustment factors based on yield grade (Black and Fox, 1977).

[h]ADG adjusted for dressing percent divided by ADG adjustment factor for yield grade.

[i]Interpolated from F/G adjustment factors based on yield grade (Black and Fox, 1977).

[j]Feed per kg of gain adjusted for dressing percent divided by F/G adjustment factor for yield grade.

had been marketed at these lighter weights, it is unknown what effect it would have had on marbling.

Average daily gain and feed/gain for heifers in Table 11 differed somewhat from steer data already presented. Breeding group 3 heifers were the highest gaining with .88 kg while BG1 remained the lowest with .76 kg per day. Feed per gain ranked the same with the greatest adjustment effect being for the BG4 heifers which were 5.7% less efficient than the next closest group (BG1). Breeding group 2 heifers were comparable with BG2 steers in that they were close to one unit/gain more efficient in the feedlot.

The return from a steer to the cow-calf producer as shown in Table 12 was a function of carcass value, total feedlot cost, beef herd out-of-pocket cost, and fertility within each breeding group. For steer value per cow unit, selected Herefords or BG2 showed a 16.5% improvement over the unselected Herefords or BG1. Breeding groups 3 and 4 showed advantages in value per cow unit of 2.5% and 9.1% over BG2, respectively. Fertility was primarily responsible for the differences between the crossbred groups and the selected group.

The return from a heifer to the cow-calf producer per cow unit was based on information from steers and had the same relative ranking as the steers. The heifers in BG2 showed a 35.3% advantage for selection over BG1. The crossbreeding advantage was 8.7% and 16.0% for BG3 and BG4. Heifer values were larger, in each comparison, than the steer differences due to selection or crossbreeding. The larger differences were caused primarily by feed per gain for BG2 and fertility for BG3 and BG4.

Table 11. Heifer Average Daily Gain and Feed Efficiency, 1972-1975[a]

Breeding group	Carcass[b] weight	ADG[c] ratio	ADG[d] Adj.	F/G[e] ratio	kg Feed per kg gain adjusted
1	229	.823	.762	1.065	8.26
2	263	.779	.875	1.082	7.32
3	281	.820	.885	1.044	8.23
4	280	.803	.857	1.113	8.73

[a]Estimated from ratio of steer to heifer performance data, 1975-1976 feed trial. Postweaning heifer performance data not obtained in other years.

[b]Steer carcass weight times 0.82.

[c]Ratio determined from data presented by Harpster et al. (1977).

[d]Steer adjusted ADG times ratio of heifer to steer gain.

[e]Ratio determined from data presented by Harpster et al. (1977).

[f]Steer adjusted feed/gain times ratio of heifer to steer F/G.

Table 12. Return from Steer to Cow-Calf Producer

Breeding Group	Steer[a] carcass value	Steer[b] feed cost	Steer[c] nonfeed cost	Total feedlot cost	Steer[d] value to feeder	Steer initial feedlot weight kg	Steer[e] value per kg	% Fertility	% Steer per cow unit	Steer[f] value per cow unit
1	431.20	180.86	59.02	239.88	191.32	187	1.01	80.3	40.2	76.91
2	494.90	193.42	76.92	270.34	224.56	208	1.08	79.7	39.9	89.60
3	529.20	216.05	97.62	313.67	215.53	249	0.86	85.1	42.6	91.82
4	527.80	212.41	97.62	310.03	217.77	257	0.84	89.7	44.9	97.78

[a]Carcass weight times steer carcass price (Table 13).

[b]Total dry matter intake times $0.088 per kg.

[c]Based on data by Crickenberger and Black (1976).

[d]Steer carcass value minus total feedlot cost.

[e]Steer value divided by steer initial feedlot weight.

[f]Steer value to feeder times percent steer per cow unit.

Table 13. Carcass Value per Kilogram[a]

Carcass weight kg	Steers $ per kg	Heifers $ per kg
273	1.54	1.52
227-273	1.52	1.50
182-227	1.50	1.48

[a]Based on price spread over a five-year period, Livestock and Meat Situation.

Table 14. Return from Heifer to Cow-Calf Producer Based on Steer Information

Breeding Group	Heifer[a] carcass value	Heifer[b] feed cost	Heifer[c] nonfeed cost	Total feedlot cost	Heifer[d] value to feeder	Heifer initial feedlot weight kg	Heifer[e] value/kg per cow unit	% Fertility	% Heifer per cow unit	Heifer[f] value per cow unit
1	343.40	158.75	59.02	239.88	125.63	162	.77	80.3	20.2	25.38
2	394.40	162.75	76.92	270.34	172.63	174	.99	79.7	19.9	34.35
3	427.80	184.88	97.62	313.67	166.00	198	.87	85.1	22.6	37.52
4	426.42	189.42	97.62	310.03	160.08	225	.70	89.7	24.9	39.86

[a] Carcass weight times heifer carcass price (Table 13).

[b] Total dry matter intake times $0.088 per kg.

[c] Based on data presented by Crickenberger and Black (1976).

[d] Heifer carcass value minus total feedlot cost.

[e] Heifer value divided by heifer initial feedlot weight.

[f] Heifer value to feeder times percent heifer per cow unit.

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Cull cow value per cow unit was determined from cow weight, dollar value based on steer value and percent culled from the cow herd. Differences ranged $6.40 from BG1 to BG3, the lowest to the highest as presented in Table 15.

Individual effects of cow weight, selection and crossbreeding on calf weaning weight in Table 16 were calculated to adjust intake of dry matter for cows for differences in weight and milk production. The additional weaning weight above that due to increase in cow weight and selection, was assumed to be due to extra milk production in BG3 and BG4.

Total intake of dry matter per cow ranged from 3,286 kg to 3,747 kg for BG1 through BG4. These results agree with those of Klosterman and Parker (1976).

Out-of-pocket cost per cow unit (Table 19) was based on dry matter intake as presented in Table 18. Breeding group 1 served as the average with a base value of $105.00 (Fox and Black, 1976). Cow unit dry matter intake considered the cow intakes of dry matter for replacement heifer and bull to arrive at a total. The costs were $108.13, $114.99, and $117.18 for BG 2, 3, and 4. Breeding group 4's costs were greater than BG3's due primarily to the adjustment for the extra weaning weight produced.

The effect of breeding group on return over out-of-pocket cost ranked consecutively larger from BG1 through BG4, as shown in Table 20. The unselected Hereford group had the lowest return followed by BG2, the selected Hereford group, with a 50.9% advantage. Crossbred groups

Table 15. Return from Cull Cow to Cow-Calf Producer

Breeding group	Cow weight	Value[a] per kg	Value[b] per head	Cull cow per cow unit	Cull cow value per cow unit
1	396	.551	218.25	.20	43.65
2	423	.551	233.25	.20	46.65
3	454	.551	250.25	.20	50.05
4	453	.551	249.50	.20	49.90

[a]Steer price per kg times .6 (Fox and Black, 1976) times 60% dress.

[b]Cow live weight times value per kg.

Table 16. Effect of Cow Weight, Selection, and Crossbreeding on Calf Weaning Weight

Group	Cow weight kg	Adj.[a] weaning weight kg	kg Calf/[b] 100 kg cow weight increase	Diff. in[c] cow weight as % of 100 kg	WW[d] Adj. for cow weight	Additional[e] kg due to cow weight	Additional[f] kg due to selection	WW Adj.[g] for cow weight and sel.	Additional[h] kg due to breed and/or crossbreeding
1	396	185	--	--	185	--	--	--	--
2	423	206	17.7	27	90	5	16	206	--
3	454	233	17.7	58	195	10	16	211	22
4	453	250	17.7	57	195	10	16	211	39

[a]All calf weaning weights shown in this table have been adjusted for age, age of dam, and sex.

[b]Expected increase in calf weight/100 kg increase in cow weight (Klosterman and Parker, 1976).

[c]Increase in cow weight over BG1 as a percent of 100 kg.

[d]Difference in kg cow weight as percent of 100 times ratio of cow weight with calf weaning weight plus weaning weight for BG1.

[e]Weaning weight adjusted for cow weight minus weaning weight for BG1.

[f]Weaning weight for BG2 minus weaning weight adjusted for cow weight for BG2.

[g]Additional kg due to selection plus weaning weight adjusted for cow weight.

[h]Weaning weight minus weaning weight adjusted for cow weight and selection.

Table 17. Additional Dry Matter Needed for Extra Calf Weaning Weight in Groups 3 and 4

Breeding group	Additional gain kg	Gain[a] requirement MCal ME/kg gain	ME[b]/kg milk DM MCal	MCal ME[c] requirement for gain	Milk[d] kg DM	12% DM[e] milk in kg	Requirement[f] MCal ME to produce kg milk	Total requirement in MCal ME	ME/kg[h] bluegrass DM, MCal	Additional kg DM needed	kg DM/kg[j] gain
3	22	6.6	4.7	145.2	30.9	257	1.13	290	2.28	127	5.77
4	39	6.6	4.7	257.4	54.8	457	1.13	516	2.28	226	5.79

[a]NRC, 1976, Nutrient Requirements of Beef Cattle.

[b]NRC, 1976, Nutrient Requirements of Beef Cattle.

[c]Additional gain in kg times requirement in MCal ME/kg gain.

[d]MCal ME requirement for gain divided by ME content in MCal/kg milk DM.

[e]Kilogram milk DM divided by .12 = kg milk, as fed.

[f]NRC, 1971, Nutrient Requirements of Dairy Cattle.

[g]Kilogram milk times requirement MCal ME to produce kg milk.

[h]NRC, 1976, Nutrient Requirements of Beef Cattle.

[i]ME required, MCal divided by bluegrass ME/kg.

[j]Additional kg bluegrass DM needed divided by additional kg gain.

Table 18. Cow Dry Matter Intake[a]

Breeding group	Lactation dry matter per day kg	Lactation days	Mid-pregnancy dry matter per day kg	Mid-pregnancy days	Late pregnancy dry matter per day kg	Late pregnancy days	Total dry matter kg
1	10.84	210	6.02	60	6.83	95	3,286
2	11.14	210	6.32	60	7.16	95	3,399
3	11.48 + .605[b]	210	6.65	60	7.54	95	3,653
4	11.46 + 1.076[b]	210	6.64	60	7.53	95	3,747

[a]Based on regression equations: .011 (cow weight, kg) + 6.50 for lactation;
.0108 (cow weight, kg) + 1.75 for mid-pregnancy;
.0122 (cow weight, kg) + 2.00 for late-pregnancy;
NRC, 1976, Nutrient Requirements of Beef Cattle.

[b]Adjusted for dry matter to produce milk for additional weaning weight, Table 16.

Table 19. Out-of-Pocket Cost per Cow Unit Based on Dry Matter Intake[a]

Breeding group	Cow[b] dry matter intake kg	Cow dry matter value/kg	Replacement[c] heifer dry matter intake kg	Replacement heifer dry matter value/kg	Bull[d] dry matter intake kg	Bull dry matter value/kg	Total out-of-pocket cost
1	3,286	.023	879	.027	227	.023	104.53
2	3,399	.023	909	.027	235	.023	108.13
3	3,653	.023	943	.027	243	.023	114.99
4	3,747	.023	941	.027	243	.023	117.18

[a]Group 1 serves as base with a cost of the average cow presented by Fox and Black (1976).

[b]Cow dry matter adjusted for milk to produce additional weaning weight within group 3 and within group 4.

[c]Replacement heifer dry matter based on .275 times mature cow dry matter intake unadjusted for milk to produce additional weaning weight within group 3 and within group 4 (Fox and Black, 1976).

[d]Bull dry matter per year based on .071 times mature cow dry matter intake unadjusted for milk to produce additional weaning weight within group 3 and within group 4 (Fox and Black, 1975).

Table 20. Return to Cow-Calf Producer per Cow Unit

Breeding group	Steer value per cow unit $	Heifer value per cow unit $	Cull cow value per cow unit $	Gross return per cow unit $	Beef herd out-of-pocket cost $	Return to beef herd over out-of-pocket cost $
1	76.91	25.38	43.65	145.94	104.53	41.41
2	89.60	34.35	46.65	170.60	108.13	62.47
3	91.82	37.52	50.05	179.39	114.98	64.41
4	97.78	39.86	49.90	187.54	117.71	69.83

had the greatest return with a 3.1% and a 11.8% advantage for BG3 and BG4 over BG2.

In conclusion, selection was the most important practice in changing the income as compared to the group where no selection had occurred. Selection was also important in the crossbred groups, especially BG3. Without the rigid selection in BG3, the selected Herefords could have surpassed, especially if the crossbred group had relied on heterosis alone.

CONCLUSIONS

Based on the results of this study, the following conclusions were made:

1. The additional milk received by the nursing crossbred heifers may have reduced their cow productivity.
2. Selection accounted for an 11.4% increase in actual weaning weight.
3. The use of rotational crossbreeding increased adjusted weaning weight by 13.1% in BG3 and 21.4% in BG4.
4. Selection for yearling weight and crossbreeding increased cow weight.
5. Selection for yearling weight did not improve fertility while crossbreeding on the average showed a 7.7% advantage over BG2.
6. Selection for yearling weight increased postweaning average daily gain.
7. Retail yield per day of age was improved by selection; crossbreeding gave a further advantage over selection.
8. Steers from BG2 were more efficient in the feedlot when adjusted to equal body fat composition.
9. Selection for yearling weight was the primary factor responsible for the increase in dollar return to a beef herd over out-of-pocket cost.

APPENDIX

Table A1. Breeding Group by Year for AI Percentage of Calves Weaned

	Breeding Group				
Year	1	2	3	4	Average
1972	40	23	53	42	39.5
1973	47	24	40	42	38.2
1974	62	70	74	84	72.5
1975	58	70	66	68	65.5
1976	72	80	82	89	80.7
Average	55.8	53.4	63.0	65.0	59.3

Table A2. Breeding Group by Year for Numbers of Saved Dams in the Fall

Year	Breeding Group 1	2	3	4	Total
1972	45	43	47	50	185
1973	49	50	50	50	199
1974	50	50	50	50	200
1975	50	50	50	50	200
1976	50	50	50	50	200
Total	244	243	247	250	984

Table A3. Breeding Group by Year for Calf Numbers Weaned

Year	Breeding Group 1	2	3	4	Total
1972	34	32	36	45	147
1973	44	42	50	51	187
1974	40	38	42	41	161
1975	45	43	45	46	179
1976	31	33	39	36	139
Total	194	188	212	219	813

Table A4. Breeding Group by Year of Percent Breed Genes

Year	Breeding Group 3		Breeding Group 4	
1972	Hereford	32.64	Hereford	35.83
	Angus	20.14	Angus	13.61
	Charolais	47.22	Holstein-Fresian	50.56
1973	Hereford	30.50	Hereford	29.41
	Angus	49.50	Angus	48.53
	Charolais	20.00	Holstein-Fresian	22.06
1974	Hereford	30.95	Hereford	31.40
	Angus	31.55	Angus	30.18
	Charolais	37.50	Holstein-Fresian	38.42
1975	Hereford	31.53	Hereford	31.25
	Angus	32.08	Angus	31.79
	Charolais	36.39	Holstein-Fresian	36.96
1976	Hereford	33.82	Hereford	31.06
	Angus	26.44	Angus	30.05
	Charolais	39.74	Holstein-Fresian	38.89

Table A5. Breeding Group by Year for Percent Calving Ease[a] Score and Breeding Group Averages

Year	Breeding Group 1		Breeding Group 2		Breeding Group 3		Breeding Group 4	
1972	1	95.6	1	97.7	1	89.4	1	86.0
	3	4.4	4	2.3	3	6.4	2	2.0
					4	4.2	3	12.0
1973	1	93.8	1	76.0	1	96.0	1	82.0
	2	2.04	2	4.0	2	2.0	2	2.0
	3	2.04	3	14.0	3	2.0	3	8.0
	4	2.04	4	6.0			4	8.0
1974	1	82.0	1	82.0	1	82.0	1	82.0
	2	2.0	2	4.0	3	12.0	2	2.0
	3	12.0	3	8.0	4	6.0	3	8.0
	4	4.0	4	6.0			4	8.0
1975	1	92.0	1	66.0	1	80.0	1	90.0
	3	8.0	2	4.0	3	18.0	2	4.0
			3	24.0	4	2.0	3	6.0
1976	1	94.0	1	70.0	1	84.0	1	90.8
	3	6.0	2	2.0	2	4.0	2	3.7
			3	20.0	3	8.0	3	5.5
			4	6.0	4	4.0		
			5	2.0				
All	1	91.5	1	78.3	1	86.3	1	86.2
	2	0.8	2	2.8	2	1.2	2	2.7
	3	6.5	3	13.2	3	9.3	3	7.9
	4	1.2	4	5.3	4	3.2	4	3.2
	5	--	5	0.4	5	--	5	--

[a]Calving ease: 1 = little or no help;
2 = hand pull;
3 = chains, light pull;
4 = chains, hard pull;
5 = cesarean.

Table A6. Least Square Means of Pooled Cow Weight by Breeding Group and Year

Year	Breeding Group 1	2	3	4	Average
1972	860	881	997	976	929
1973	807	862	875	890	859
1974	914	980	1,059	1,046	1,000
1975	875	962	1,039	1,029	976
1976	910	981	1,035	1,050	994
Average	873	933	1,001	998	951

Table A7. Least Square Means of 2-Year-Old Cow Weight by Breeding Group and Year

	Breeding Group				
Year	1	2	3	4	Average
1972	618	698	786	847	737
1973	637	674	754	841	727
1974	767	831	950	953	875
1975	725	835	883	974	854
1976	677	789	822	931	805
Average	685	765	839	909	800

Table A8. Least Square Means of Pooled Cows for Fraction Weaned by Breeding Group and Year

	Breeding Group				
Year	1	2	3	4	Average
1972	.739	.744	.791	.868	.786
1973	.857	.840	.905	.977	.895
1974	.820	.780	.844	.900	.836
1975	.900	.860	.887	.933	.895
1976	.700	.760	.829	.807	.774
Average	.803	.797	.851	.897	.837

Table A9. Least Square Means of 2-Year-Old Cows for Fraction Calves Weaned by Breeding Group and Year

	Breeding Group				
Year	1	2	3	4	Average
1972	.500	.500	.988	.748	.684
1973	.556	.545	.988	.964	.763
1974	.818	.500	.888	.865	.768
1975	1.000	.600	.805	.786	.798
1976	.700	.500	.800	.590	.648
Average	.715	.529	.895	.791	.732

Table A10. Least Square Means of Pooled Cows for Calving Difficulty Score by Breeding Group and Year

	Breeding Group				
Year	1	2	3	4	Average
1972	1.11	1.08	1.33	1.23	1.19
1973	1.14	1.56	1.12	1.34	1.29
1974	1.40	1.39	1.52	1.34	1.41
1975	1.16	1.70	1.48	1.09	1.36
1976	1.09	1.70	1.36	1.06	1.34
Average	1.18	1.49	1.36	1.21	1.31

Table A11. Least Square Means of 2-Year-Old Cows for Calving Difficulty Score by Breeding Group and Year

Year	Breeding Group 1	2	3	4	Average
1972	1.67	2.00	2.28	1.58	1.88
1973	1.20	2.13	2.08	2.28	1.92
1974	2.45	2.27	2.88	1.59	2.30
1975	1.80	2.80	1.99	1.83	2.11
1976	1.40	3.10	2.00	1.25	1.94
Average	1.70	2.46	2.25	1.71	2.03

Table A12. Phenotypic Maternal Correlation Data Format

	Card column	Code
Year	1-2	Actual
Breeding group	3	Actual
Breed of sire	4-7	2-Hereford 3-Angus 6-Charolais 7-Holstein
Cow number	8-11	Actual
Age	12-13	Actual
Fall weight	14-17	Actual
Weaning weight	18-20	Actual
Adjusted weaning weight	21-23	Actual
Weaning conformation grade	24-25	11 = high good 12 = low choice, etc.
18-month weight	26-29	Actual
Calf number	30-33	Actual
Sex	34	1 = bull 2 = heifer 3 = steer
Weaning weight	35-37	Actual
Adjusted weaning weight	38-40	Actual
Weaning conformation grade	41-42	11 = high good 12 = low choice, etc.

Table A13. Calf Data Format

	Card column	Code
Calf number	2-4	Actual
Dam number	5-8	Actual
Sire number	9-12	Actual
Sex	13	1 = bull 2 = heifer 3 = steer
Birth date	14-19	Actual
Age of dam	20-21	Actual
Breeding group	22	Actual
Breed of sire	23-26	2 = Hereford 3 = Angus 6 = Charolais 7 = Holstein
Birth weight	27-29	Actual
RS replacement sire	30	0
Date weighed (weaning)	31-36	Actual
Weaning weight	37-38	Actual
Weaning conformation grade	40-41	11 = high good 12 = low choice, etc.
Adjusted weaning weight	42-44	Actual
Date weighed (yearling)	45-50	Actual
Yearling weight	51-54	Actual
Yearling conformation grade	55-56	11 = high good 12 = low choice, etc.
Adjusted yearling weight	57-60	Actual
ADG times 100	61-63	Actual
Dam's bull assignment while nursing this calf	80	2 = Hereford 3 = Angus 6 = Charolais 7 = Holstein

Table A14. Dam Data Format

	Card column	Code
Year	1-2	Actual
Breeding group	3	Actual
Breed of sire	4-7	2 = Hereford 3 = Angus 6 = Charolais 7 = Holstein
Cow number	11-14	Actual
Age	15-16	Actual
Fall weight	17-20	Actual
Spring weight	21-24	Actual
AI bull number (coded)	25-27	Code
Date bred AI	29-34	Actual
Calf weight	35-37	Actual
Settle AI (yes, no)	38	1 = yes, 2 = no
Save (yes, no)	39	1 = yes, 2 = no
Reason culled	40	1 = old 2 = open 3 = open and old 4 = cancer 5 = cancer and open 7 = died 8 = light calf 9 = other
Calf number	41-44	Actual
Sex	45	1 = bull 2 = heifer 3 = steer
Calving difficulty	46	1 = little or no help 2 = hand pull 3 = chains, light pull 4 = chains, hard pull 5 = cesarean
Calf born alive	47	
AI sire (yes, no)	48	1 = yes, 2 = no
Date calved	49-54	Actual
Sire of calf	55-57	Actual
Calved last year	71	1 = yes, 2 = no
Days pregnant in fall	72-74	Actual
Times bred AI	75	Actual
Sire of dam	76-78	Actual
Cow hundred number (0 or 1)	79	0 or 1
Breeding group (preceding summer)	80	Actual

Table A15. Steer Data Format

	Card column	Code	Calf crop years			
			1972	1973	1974	1975
Year	1	Actual				
Animal number	2-6	Actual				
Treatment	7		No treatment	60% Concentrate 1 = Control 2 = Synovex 3 = Ralgro	1 = H. energy 2 = L. energy	1 = H. energy 2 = L. energy
Breeding group	9	Actual				
Breed of sire	11-14	2 = Hereford 3 = Angus 6 = Charolais 7 = Holstein				
Sire	16-19	Actual				
Initial weight	21-23	Actual				
Days on feed	27-29	Actual				
Final weight	30-33	Actual				
Hot carcass weight	35-37	Actual				
Conformation grade	38-39	Good 9, 10, 11, etc.				
Maturity	42-43	$A^- = 1$ $A^\circ = 2$ $A^+ = 3$				
Marbling	40-41	Small 10, 11, 12, etc.				
Quality grade	44-45	Good 9, 10, 11, etc.				
Kidney, heart, pelvic fat	46-47	Actual				
Graders cutability	48-49	Actual				
External fat	50-52	Actual				
Rib eye area	53-56	Actual				
Late weight	57-60	Actual				

Table A16. Mean Squares for Weaning Traits

Source of variation	Age of dam	df	Weaning weight	205-Day weight	Weaning grade	Calving ease	Cow weight	Cow fertility
Breeding group (BG)	Pooled	3	186,887**	165,187**	5.29**	4.25**	202,709**	.46*
	2	3	45,954**	37,321**	.70	4.73**	117,501**	.88**
Year (Y)	Pooled	4	135,268**	103,773**	13.00**	1.20	175,381**	.65**
	2	4	30,393**	24,802**	3.52**	1.07	41,632**	.15
BG x Y	Pooled	12	2,980**	3,101**	.91	1.46**	4,998	.04
	2	12	1,323	623	.38	1.82	1,280	.14
Error[a]	Pooled	791	956	617	.57	.60	3,990	.13
	2	123	828	587	.43	1.20	985	.18

[a]Error degrees of freedom for calving ease, cow weight, and cow fertility were 897, 1,168, and 967 for pooled ages and 158, 246, and 175 for 2-year-old dams, respectively.

*$P < .05$.

**$P < .01$.

Table A17. Mean Squares for Feedlot and Carcass Traits

Source of variation	df	Initial weight	Final weight	Average daily gain	Marbling	Quality grade	Percent cutability	Percent retail yield	Percent yield per day of age
Breeding group (BG)	3	52,592**	106,904**	.179**	59.7**	4.48*	29.7**	.011**	.240**
Year (Y)	3	36,392**	16,239**	.060**	46.1**	5.04*	29.7**	.011**	.035**
BG x Y	9	1,138	2,273	.012	7.8	1.50	5.1*	.002*	.003
Error	187	910	1,922	.012	11.6	1.64	2.6	.001	.008

*P < .05.

**P < .01.

LITERATURE CITED

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Black, J. R. and D. G. Fox. 1977. Interpretation and use of research results. Mich. Agr. Exp. Sta. Res. Rep. 328.

Boston, Andrew C., J. W. Whiteman and R. R. Frahm. 1975. Phenotypic relationships within Angus and Hereford females: I. Heifer growth and subsequent cow productivity. J. Anim. Sci. 41:16.

Brinks, J. S., R. T. Clark, N. M. Kieffer and J. J. Urick. 1964. Predicting producing ability in range Hereford cows. J. Anim. Sci. 23:593.

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

Brinks, J. S., B. W. Knapp, J. J. Urick and O. F. Pahnish. 1972. Heterosis in preweaning maternal traits among lines of Hereford cattle. J. Anim. Sci. 34:1.

Christian, L. L., E. R. Hauser and A. B. Chapman. 1965. Association of preweaning and postweaning traits weaning weight in cattle. J. Anim. Sci. 24:652.

Crichton, J. A., J. N. Aitken and A. W. Boyne. 1960. The effect of plane of nutrition during rearing on growth, production, reproduction and health of dairy cattle. I. Growth to 24 months. Anim. Prod. 1:145.

Crickenberger, R. G. and J. R. Black. 1976. Influence of frame size on performance and economics considerations of feedlot cattle. Mich. Agr. Exp. Sta. Rep. 318.

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

Cundiff, L. V., K. E. Gregory, F. J. Schwulst and R. M. Koch. 1974. Effects of heterosis on maternal performance and milk production in Hereford, Angus and Shorthorn cattle. J. Anim. Sci. 38:728.

Davis, H. P. and E. L. Willett. 1938. Relationship between rats of growth and fat production. J. Dairy Sci. 21:637.

Deese, R. E. and M. Kroger. 1967. Maternal effects on preweaning growth rate in cattle. J. Anim. Sci. 26:250.

Deutscher, G. H. and J. V. Whiteman. 1971. Productivity as two-year olds of Angus-Holstein crossbreds compared to Angus heifers under range conditions. J. Anim. Sci. 33:337.

Drewery, K. J., C. J. Brown and R. S. Honea. 1959. Relationships among factors associated with mothering ability in beef cattle. J. Anim. Sci. 18:938.

Dunn, R. J., W. T. Magee, K. E. Gregory, L. V. Cundiff and R. M. Koch. 1970. Genetic parameters in straightbred and crossbred beef cattle. J. Anim. Sci. 31:656.

Ewing, S. A., L. Smithson, C. Ludwig and D. Stephens. 1968. Energy requirements of mature beef cows as influenced by weight and level of milk production. Okla. Agr. Exp. Sta. Misc. Pub. 80.

Fox, D. G. 1977. Personal Communication.

Fox, D. G. and J. R. Black. 1975. The influence of cow size, slaughter weight, crossbreeding, feeding system and environment on the energetic and economic efficiency of edible beef production. Proc. 1975 Reciprocal Meats Conf.

Fox, D. G. and J. R. Black. 1976. Producing beef: What it costs and opportunities for improving efficiency. Paper presented at Symposium "Quality Beef for the Consumer," 1976 Annual Meeting, American Society of Animal Science.

Gaines, J. A., W. H. McClure, D. W. Vogt, R. C. Carter and C. M. Kincaid. 1966. Heterosis from crosses among British breeds of beef cattle: Fertility and calf performance to weaning. J. Anim. Sci. 25:5.

Gaines, J. A., G. V. Richardson, W. H. McClure, D. W. Vogt and R. C. Carter. 1967. Heterosis from crosses among British breeds of beef cattle: Carcass characteristics. J. Anim. Sci. 26:1217.

Gould, M. B. and J. V. Whiteman. 1975. Relationship between preweaning growth rate of female lambs and the growth rate of their offspring. J. Anim. Sci. 40:585.

Gregory, K. E. 1961. Improvement of beef cattle through breeding methods. North Central Regional Publ. 120.

Gregory, K. E. 1965. Symposium on performance testing in beef cattle: Evaluating postweaning performance in beef cattle. J. Anim. Sci. 24:248.

Gregory, K. E. 1972. Beef cattle type for maximum efficiency "Putting it all together." J. Anim. Sci. 34:881.

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

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

Gregory, K. E., L. A. Swiger, L. J. Sumption, R. M. Koch, J. E. Ingalls, W. W. Rowden and J. A. Rothlisberger. 1966b. Heterosis effects on carcass traits of beef steers. J. Anim. Sci. 25:311.

Hansson, A. 1956. Influence of rearing intensity on body development and milk production. Proc. British Soc. Anim. Sci. Prod. p. 50.

Harpster, H. W., D. G. Fox and W. T. Magee. 1977. Energy requirements of cows and feedlot performance of steer and heifer calves of four genetic groups. Mich. Agr. Exp. Sta. Res. Rep. 328.

Harvey, W. R. 1960. Least-square analysis of data with unequal subclass numbers U.S.D.A., A.R.S. 20-8.

Hedrick, H. B. 1972. Beef cattle type and body composition for maximum efficiency. J. Anim. Sci. 34:870.

Hedrick, H. B., G. F. Krause, J. F. Lasley, B. Sibbit, L. Langford and A. J. Dyer. 1975. Quantitative and qualitative carcass characteristics of straightbred and reciprocally crossed Angus, Charolais and Hereford steers. J. Anim. Sci. 41:1581.

Hill, J. R., Jr. 1956. The inheritance of maternal effects in beef cattle. Ph.D. Thesis. North Carolina State University, Raleigh.

Hohenboken, W. D. and J. S. Brinks. 1971. Relationship between direct and maternal effects on growth in Herefords: II. Partitioning of covariance between relatives. J. Anim. Sci. 32:26.

Holty, E. W., R. E. Erb, and A. S. Hodgson. 1961. Relationship between rate of gain from birth to six months of age and subsequent yields of dairy cows. J. Dairy Sci. 44:672.

Johansson, I. 1964. The relation between body size, conformation and milk yield in dairy cattle. Animal Breeding Abstr. 32:421.

Klosterman, Earle W. 1972. Beef cattle size for maximum efficiency. J. Anim. Sci. 34:875.

Klosterman, E. W. and C. F. Parker. 1976. Effect of size, breed and sex upon feed efficiency in beef cattle. Ohio Agr. Res. Dev. Ctr. Res. Bull. 1088.

Koch, R. M. 1969. Influence of dam's environment on offspring phenotype. J. Anim. Sci. 29:108 (Abstr.).

Koch, R. M. 1972. The role of maternal effects in animal breeding. VI. Maternal effects in beef cattle. J. Anim. Sci. 35:1316.

Koch, R. M. and R. T. Clark. 1955a. Genetic and environmental relationships among economic characters in beef cattle. II. Correlations between offspring and dam and offspring and sire. J. Anim. Sci. 14:786.

Koch, R. M. and R. T. Clark. 1955b. Genetic and environmental relationships among economic characters in beef cattle. III. Evaluation maternal environment. J. Anim. Sci. 14:979.

Koch, R. M., K. E. Gregory and L. V. Cundiff. 1974. Selection in beef cattle. II. Selection response. J. Anim. Sci. 39:459.

Kress, D. D. and P. J. Burfening. 1972. Weaning weight related to subsequent most probable producing ability in Hereford cows. J. Anim. Sci. 35:327.

Lasley, J. F., G. F. Krause, J. P. Jain, H. B. Hedrick, B. Sibbit, L. Langford, J. E. Comfort and A. J. Dyer. 1971. Carcass quality characteristics in heifers of reciprocal crosses of the Angus, Charolais and Hereford breeds. J. Anim. Sci. 32:406.

Lindholm, Howard B. and H. H. Stonaker. 1957. Economic importance of traits and selection indexes for beef cattle. J. Anim. Sci. 16:998.

Long, C. R. and K. E. Gregory. 1974. Heterosis and breed effects in preweaning traits of Angus, Hereford and reciprocal cross calves. J. Anim. Sci. 39:1.

Long, C. R. and K. E. Gregory. 1975a. Heterosis and management effects on postweaning growth of Angus, Hereford and reciprocal cross cattle. J. Anim. Sci. 41:1563.

Long, C. R. and K. E. Gregory. 1975b. Heterosis and management effects in carcass characters of Angus, Hereford and reciprocal cross cattle. J. Anim. Sci. 41:1572.

Lush, J. L. 1948. The genetics of populations. Mimeo. Publ.

Magee, W. T. 1974. Changing the genetic ability of commercial cow herds. Mich. Agr. Exp. Sta. Res. Rep. 256.

Magee, W. T. and T. R. Greathouse. 1969. Changing the genetic ability of commercial cow herds. Mich. Agr. Exp. Sta. Res. Rep. 90.

Magee, W. T. and T. R. Greathouse. 1970. Changing the genetic ability of commercial cow herds. Mich. Agr. Exp. Sta. Res. Rep. 118.

Magee, W. T. and T. R. Greathouse. 1971. Changing the genetic ability of commercial cow herds. Mich. Agr. Exp. Sta. Res. Rep. 141.

Magee, W. T. and T. R. Greathouse. 1972. Changing the genetic ability of commercial cow herds. Mich. Agr. Exp. Sta. Res. Rep. 166.

Magee, W. T. and T. R. Greathouse. 1973. Changing the genetic abiltiy of commercial cow herds. Mich. Agr. Exp. Sta. Res. Rep. 226.

Magee. W. T. and C. A. McPeake. 1975. Changing the genetic ability of commercial cow herds. Mich. Agr. Exp. Sta. Res. Rep. 288.

Magee, W. T. and C. A. McPeake. 1976. Changing the genetic ability of commercial cow herds. Mich. Agr. Exp. Sta. Res. Rep. 318.

Mangus, W. L. and J. S. Brinks. 1969. Factors affecting beef cow productivity. J. Anim. Sci. 29:109 (Abstr.)

Mangus, W. L. and J. S. Brinks. 1971. Relationships between direct and maternal effects on growth in Herefords: I. Environmental factors during preweaning growth. J. Anim. Sci. 32:17.

Marchello, J. A., D. W. Blackmore and J. J. Urick. 1960. Heritability of 18-month weight of heifers and its relationship to birth weight and weaning weight of their first calf. J. Anim. Sci. 19:956 (Abstr.).

Mason, I. L. 1966. Hybrid vigour in beef cattle. Animal Breeding Abstr. 34:453.

Mather, K. 1955. A discussion on hybrid vigor. Proc. of Royal Soc. of London, Series B, Biol. Sci., Vol. 144.

Nelms, G. E. and P. O. Stratton. 1967. Selection practiced and phenotypic change in a closed line of beef cattle. J. Anim. Sci. 26:274.

Neville, W. E., Jr. 1962. Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci. 21:320.

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N.R.C. 1971. Nutrient Requirements of Dairy Cattle, No. 3 Revised 1971, ISBN0-309-01916-8. National Academy of Science--National Research Council, Washington, D.C.

N.R.C. 1976. Nutrient Requirements of Beef Cattle, No. 4, Revised 1976, ISBN0-309-02419-6. National Academy of Science--National Research Council, Washington, D.C.

Pahnish, O. F., J. S. Brinks, J. J. Urick, B. W. Knapp and T. M. Riley. 1969. Results from crossing beef x beef and beef x dairy breeds: Calf performance to weaning. J. Anim. Sci. 28:291.

Plum, Mogens and Lionel Harris. 1968. Rearing intensity and milk production. J. Anim. Sci. 27:1128 (Abstr.).

Rollins, W. C., R. G. Loy, F. D. Carroll and K. A. Wagnon. 1969. Heterotic effects in reproduction and growth to weaning in crosses of the Angus, Hereford and Shorthorn breeds. J. Anim. Sci. 28:431.

Rutledge, J. J., O. W. Robinson, W. T. Ahlschwede and J. E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 33:3.

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

Schultz, L. H. 1969. Relationship of rearing rate of dairy heifers to mature performance. J. Dairy Sci. 52:1321.

Schwulst, F. J., R. M. Koch, K. E. Gregory, L. V. Cundiff and L. J. Sumption. 1968. Heterosis of milk production in beef cows. J. Anim. Sci. 27:1129 (Abstr.)

Sidwell, George M. and Larry R. Miller. 1971a. Production in some pure breeds of sheep and their crosses. I. Reproductive efficiency in ewes. J. Anim. Sci. 32:1084.

Sidwell, George M. and Larry R. Miller. 1971b. Production in some pure breeds of sheep and their crosses. II. Birth weights and weaning weights of lambs. J. Anim. Sci. 32:1090.

Singh, A. R., R. R. Schalles, W. H. Smith and F. B. Kessler. 1970. Cow weight and preweaning performance of calves. J. Anim. Sci. 31:27.

Swanson, E. W. 1960. Effect of rapid growth with fattening of dairy heifers on their lactational ability. J. Dairy Sci. 43:377.

Swanson, E. W. 1967. Optimum growth patterns for dairy cattle. J. Dairy Sci. 50:244.

Swanson, E. W. and T. R. Spann. 1964. The effect of rapid growth with fattening upon lactation in cattle and rats. J. Anim. Sci. 13:1032 (Abstr.).

Swanson, E. W. and S. A. Hinton. 1964. Effect of seriously restricted growth upon lactation. J. Dairy Sci. 47:267.

Swiger, L. A., Robert M. Koch, K. E. Gregory and V. H. Arthand. 1962. Selecting beef cattle for economical gain. J. Anim. Sci. 21:588.

Thomas, J. W., J. F. Sykes and L. A. Moore. 1959. Comparisons of alfalfa hay and alfalfa silage along with supplements of grain, hay or corn silage for growing dairy calves. J. Dairy Sci. 42:651.

Totusek, Robert. 1968. Early weaning vs. normal weaning vs. creep feeding of heifer calves. Okla. Agr. Exp. Sta. Pub. No. MP-80, p. 72.

Totusek, R., D. F. Stephens, J. R. Kropp, J. W. Holloway, L. Knori and J. V. Whiteman. 1971. Milk production of range cows. Okla. Agr. Exp. Sta. Misc. Pub. 85, p. 18.

Urick, J. J., B. W. Knapp, J. S. Brinks, O. F. Pahnish and T. M. Riley. 1971. Relationships between cow weights and calf weaning weights in Angus, Charolais and Hereford breeds. J. Anim. Sci. 33:343.

Urick, J. J., B. W. Knapp, R. L. Hiner, O. F. Pahnish, J. S. Brinks and R. L. Blackwell. 1974. Results from crossing beef x beef and beef x Brown Swiss: Carcass quantity and quality traits. J. Anim. Sci. 39:292.

U.S.D.A. 1972. Guidelines for Uniform Beef Improvement Programs. Program Aid 1020.

U.S.D.A. 1973. Official United States standards for grades of carcass beef. Title 7, Ch. I, Pt. 53, sec. 53. 100-53. 105. Code of Fed. Reg.

Vogt, D. W. and T. J. Marlowe. 1966. A further study of the genetic parameters involving preweaning growth rate and weaning grade in beef calves. J. Anim. Sci. 25:265 (Abstr.).

Vogt, D. W., J. A. Gaines, R. C. Carter, W. H. McClure and C. M. Kincaid. 1967. Heterosis from crosses among British breeds of beef cattle: Postweaning performance to slaughter. J. Anim. Sci. 26:443.

Willham, R. L. 1972. Beef production for maximum efficiency. J. Anim. Sci. 34:864.