A study of the relationship between growth traits and carcass characteristics in beef cattle
by Richard Archie Henderson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree
MASTER OF SCIENCE in Animal Science
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Abstract:
Cattle records of the North Montana Branch Experiment Station at Havre, Montana covering a 15-year period (1952-1966) were analyzed by simple correlation and regression analyses to study the effect of growth traits on carcass characteristics. The study consists of two parts: (a) phenotypic correlations of 8 production traits of" crossline Hereford steers with 27 of their slaughter or carcass traits (n = 339); (b) 78 sires and their respective steer progeny groups in which 10 sire production traits were correlated with 27 slaughter or carcass progeny group means. The two studies were each sub-grouped into two time periods: period 1 (1952-59) during which the animals were slaughtered after a time-constant feeding period, and period 2 (1960-66) during which they were slaughtered on a relatively weight-constant basis.

In (a) period 1, all growth traits were significantly (P<.05) correlated with carcass size. In (a) period 2, highly significant (P<.01) negative correlations were obtained between all growth traits and slaughter age. Birth weight was negatively correlated with carcass grade in both time periods. Weanling traits were positively correlated with grade in period I and negatively correlated in period 2, while feedlot traits were negatively correlated with grade in period 1 but positively correlated in period 2. All growth traits were positively correlated with measures of carcass fatness. Preweaning growth had a stronger influence on carcass fatness than did postweaning growth. During period 2 a negative relationship was found between daily gain and fat thickness. Growth traits had a highly significant positive (P<.01) effect on rib-eye area in period 1.

All growth traits were negatively correlated with rib-eye area per 100 pounds of carcass weight. Growth was negatively correlated with cutability and showed little relationship with marbling score.

In the study (b) sire feedlot, traits influenced progeny slaughter and carcass measurements more than did sire weanling traits. A positive relationship was found with area of rib-eye during period 1 with sire score at end of feed test and with sire gain per day of age, both being significantly (P<.05) correlated. Sire growth traits were also associated with a , decrease in progeny fatness measured at the 12th rib. Faster-growing and higher-scoring bulls tended to produce offspring of higher cutability. Statistical relationships among sire growth rates and scores and their respective progeny carcass traits were somewhat divergent between period I and 2.

Heritabilfty estimates were made for several production traits utilizing the regression of offspring on sire: birth weight, 50%;'weaning weight, 6%; 180-day adjusted weaning weight, 1%; final weight, 53%; average daily gain on feed, 34%; and daily gain from birth to weaning, 4%..

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A STUDY OF THE RELATIONSHIP BETWEEN GROWTH TRAITS AND CARCASS CHARACTERISTICS IN BEEF CATTLE

by

RICHARD ARCHIE HENDERSON

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TABLE OF CONTENTS

INDEX TO TABLES

ABSTRACT

Cattle records of the North Montana Branch Experiment Station at Havre, Montana covering a 15-year period (1952-1966) were analyzed by simple correlation and regression analyses to study the effect of growth traits on carcass characteristics. The study consists of two parts: (a) phenotypic correlations of 8 production traits of crossline Hereford steers with 27 of their slaughter or carcass traits (n = 339); (b) 78 sires and their respective steer progeny groups in which 10 sire production traits were correlated with 27 slaughter or carcass progeny group means. The two studies were each sub-grouped into two time periods: period 1 (1952-59) during which the animals were slaughtered after a time-constant feeding period, and period 2 (1960-66) during which they were slaughtered on a relatively weight-constant basis.

In (a) period 1, all growth traits were significantly ($P < .05$) correlated with carcass size. In (a) period 2, highly significant ($P < .01$) negative correlations were obtained between all growth traits and slaughter age. Birth weight was negatively correlated with carcass grade in both time periods. Weanling traits were positively correlated with grade in period 1 and negatively correlated in period 2, while feedlot traits were negatively correlated with grade in period 1 but positively correlated in period 2. All growth traits were positively correlated with measures of carcass fatness. Preweaning growth had a stronger influence on carcass fatness than did postweaning growth. During period 2 a negative relationship was found between daily gain and fat thickness. Growth traits had a highly significant positive ($P < .01$) effect on rib-eye area in period 1. All growth traits were negatively correlated with rib-eye area per 100 pounds of carcass weight. Growth was negatively correlated with cutability and showed little relationship with marbling score.

In the study (b) sire feedlot traits influenced progeny slaughter and carcass measurements more than did sire weanling traits. A positive relationship was found with area of rib-eye during period 1 with sire score at end of feed test and with sire gain per day of age, both being significantly ($P < .05$) correlated. Sire growth traits were also associated with a decrease in progeny fatness measured at the 12th rib. Faster-growing and higher-scoring bulls tended to produce offspring of higher cutability. Statistical relationships among sire growth rates and scores and their respective progeny carcass traits were somewhat divergent between period 1 and 2.

Heritability estimates were made for several production traits utilizing the regression of offspring on sire: birth weight, 50%; weaning weight, 6%; 180-day adjusted weaning weight, 1%; final weight, 53%; average daily gain on feed, 34%; and daily gain from birth to weaning, 4%.

INTRODUCTION

In recent years the importance of records of performance in the beef cattle industry has become increasingly evident. This has been brought about primarily by increased competition within the meat production industry plus an ever-narrowing profit margin to the beef producer due to increased operating costs.

Of equal importance is the relationship between these various records of performance and measures of carcass quality. Since the beef carcass is essentially the end product or result of the production process, and since the ultimate criterion of the worth of a beef animal is the value of its carcass, the producer must concern himself with those factors which most affect the quality of that carcass. Competition dictates that the retailer pay more for good cutting carcasses than for those of lower yield. This in turn influences the price paid the feeder and, consequently, the cow-calf operator.

It is important to know the relative weight to place on the various measures of production in our selection indexes in order to make the most rapid progress in beef cattle carcass improvement. Close relationships between any of the live animal characteristics and one or more important carcass traits could afford an opportunity for carcass improvement through established records of performance. Considerable work has been done concerning the analysis of these relationships between production and carcass measurements. The purpose of this study is to add knowledge to that obtained by previous workers with the hope of establishing a clearer understanding of these relationships.

REVIEW OF LITERATURE

Considerable research has been accomplished concerning the relationships among production traits and carcass quality. It becomes apparent upon review of the literature that for some of the relationships, both positive and negative results can be cited. Consequently, it is difficult to organize the findings into concise clear-cut pictures.

This review examines a portion of the phenotypic and genetic correlations reported among production traits and carcass traits and some heritability estimates advanced for certain of these production traits. Due to the large number of authors and results, this review is presented in table form for brevity and ease of examination.

Phenotypic Correlations

Tables I, II, III, IV and V present reported phenotypic correlations of various carcass traits with birth weight, weaning weight (actual and 180-day adjusted), final weight, average daily gain on feed and gain per day of age, respectively. A brief notation on each study concerning materials and methods, etc. is presented the first time the study is quoted.

TABLE I. PHENOTYPIC CORRELATIONS BETWEEN BIRTH WEIGHT AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Authors and remarks
Slaughter weight	.48	Woodward *et al.* (1954). Time constant feed period of 252 days. Involves records from 635 steers from the U.S. Range Livestock Experiment Station, Miles City, Montana.
	.46	Shelby *et al.* (1963). Involves 616 steers, time constant feeding period of 252 days. Also contains data from the Miles City Station and probably uses some records common to Woodward *et al.* (1954) and Woodward *et al.* (1959).
Days to slaughter	-.39	Yao *et al.* (1953). Involves 101 beef Shorthorn and 62 Milking Shorthorn steers. Cattle were slaughtered at 900 pounds.
Carcass grade	-.18	Yao *et al.* (1953).
	-.04	Woodward *et al.* (1954).
	.08	Woodward *et al.* (1959). Continuation of Woodward *et al.* (1954). Involves 210 steers. 9-10-11th rib separations were done on 56 of these. Feed period was 252 days.
	-.09	Brown *et al.* (1962). Time constant feeding trial. Involves only 11 animals.
	-.05	Shelby *et al.* (1963).
Carcass weight	.40	Shelby *et al.* (1963).
Dressing percent	-.13	Yao *et al.* (1953).
	-.05	Woodward *et al.* (1959).
	.00	Brown *et al.* (1962).
	-.02	Shelby *et al.* (1963).
Rib-eye area	.26	Woodward *et al.* (1954). Partial correlation holding final weight constant was .07.
	.12	Woodward *et al.* (1959).
	-.03	Brown *et al.* (1962).
	.17	Shelby *et al.* (1963).

TABLE I. (Continued)

Slaughter or carcass trait	r	Authors and remarks
Fat thickness	-.07	Woodward *et al.* (1954). Partial correlation holding final weight constant was -.24.
	.05	Woodward *et al.* (1959).
	-.04	Shelby *et al.* (1963).
Width of round	.21	Woodward *et al.* (1959).
Width of shoulder	.24	Woodward *et al.* (1959).
Depth of body	.30	Woodward *et al.* (1959).
Circumference of round	.10	Woodward *et al.* (1959).
Plumpness index	-.14	Woodward *et al.* (1959).
Length of body	.40	Woodward *et al.* (1954). Partial correlation holding final weight constant was .06.
	.42	Woodward *et al.* (1959).
	.36	Shelby *et al.* (1963).
Length of leg	.45	Woodward *et al.* (1954). Partial correlation holding final weight constant was .23.
	.43	Woodward *et al.* (1959).
	.44	Shelby *et al.* (1963).
Shear force	.09	Woodward *et al.* (1959).
	-.03	Brown *et al.* (1962).
Percent lean	.07	Woodward *et al.* (1959).
Percent fat	-.06	Woodward *et al.* (1959).
Percent bone	.10	Woodward *et al.* (1959).

The magnitude of the correlations reported indicate that birth weight is not a strong indicator of future performance as far as carcass traits are concerned. The strongest relationships appear to be with slaughter weight, carcass weight, length of body and length of leg. Thus, it appears birth weight is more indicative of future growth and size than it is of eventual carcass quality as determined by present quality standards.

TABLE II. PHENOTYPIC CORRELATIONS BETWEEN WEANING WEIGHT AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Authors and remarks
Slaughter weight	.60	Woodward et al. (1954).
	.63	Lindholm and Stonaker (1957). This study involved 118 Hereford steers slaughtered at a live grade of Low Choice.
	.62	Woodward et al. (1959). Weaning weight was adjusted to 180 days.
	.53	Blackwell et al. (1962). This study involved slaughter data from 421 steers killed at the conclusion of a 168 day fattening period. The steers were approximately 2 years old at the time of slaughter.
	.58	Shelby et al. (1963). 180 day weaning weight.
	.55	Christian et al. (1965). This study involves carcass data on 64 steers and heifers slaughtered at an estimated live grade of High Choice.
	.83	Dubose et al. (1967). 180 day weaning weight. Involved 231 crossbred calves slaughtered after a 140-day gain test. Average slaughter age was 424 days.
Slaughter age	-.40	Christian et al. (1965).
Carcass grade	.15	Woodward et al. (1965). Partial correlation holding final weight constant was .06.
	.23	Carter and Kincaid (1959). Weaning weight was expressed as 182 day weight. The study involved 195 Hereford and crossbred steers

TABLE II. (Continued)

Slaughter or carcass trait	r	Authors and remarks
Carcass grade (Continued)		slaughtered at the end of a 200 day test.
	.03	Woodward *et al*. (1959). 180 day weaning weight.
	.11	Blackwell *et al*. (1962).
	.09	Shelby *et al*. (1963). 180 day weaning weight.
	-.26	Christian *et al*. (1965).
	.06	Swiger *et al*. (1965). This study involved 480 steers, bulls and heifers slaughtered after a time constant feed period. Some of the animals were straightbred and some were crossbreds.
	.05	Dubose *et al*. (1967). 180 day weaning weight.
Carcass weight	.54	Blackwell *et al*. (1962).
	.57	Shelby *et al*. (1963). 180 day weaning weight.
	.70	Dubose *et al*. (1967). 180 day weaning weight.
Dressing percent	.12	Woodward *et al*. (1959). 180 day weaning weight.
	.14	Blackwell *et al*. (1962).
	.18	Shelby *et al*. (1963). 180 day weaning weight.
Rib-eye area	.30	Woodward *et al*. (1954). Partial correlation holding final weight constant was .26.
	.17	Woodward *et al*. (1959). 180 day weaning weight.
	.60	Brown *et al*. (1962).
	.24	Shelby *et al*. (1963). 180 day weaning weight.
	.52	Christian *et al*. (1965).
	.29	Dubose *et al*. (1967). 180 day weaning weight.
Fat thickness	.12	Woodward *et al*. (1954). Partial correlation holding final weight constant was .25.
	.19	Woodward *et al*. (1959). 180 day weaning weight.
	.14	Shelby *et al*. (1963). 180 day weaning weight.
	-.02	Christian *et al*. (1965).
	.18	Swiger *et al*. (1965).
	.02	Dubose *et al*. (1967). 180 day weaning weight.

TABLE II. (Continued)

Slaughter or carcass trait	r	Authors and remarks
Width of round	.40	Woodward et al. (1959). 180 day weaning weight.
	.32	Dubose et al. (1967). 180 day weaning weight.
Width of shoulder	.38	Woodward et al. (1959). 180 day weaning weight.
Depth of body	.29	Woodward et al. (1959). 180 day weaning weight.
Circumference of round	.26	Woodward et al. (1959). 180 day weaning weight.
Plumpness index	-.07	Woodward et al. (1959). 180 day weaning weight.
Length of body	.57	Woodward et al. (1959). 180 day weaning weight.
	.51	Shelby et al. (1963). 180 day weaning weight.
	.69	Dubose et al. (1967). 180 day weaning weight.
Length of leg	.59	Woodward et al. (1959). 180 day weaning weight.
	.50	Shelby et al. (1963). 180 day weaning weight.
	.50	Dubose et al. (1967). 180 day weaning weight.
Cutability	-.18	Swiger et al. (1965).
Shear force	.05	Woodward et al. (1959). 180 day weaning weight.
Marbling score	-.36	Christian et al. (1965).

TABLE II. (Continued)

Slaughter or carcass trait	r	Authors and remarks
Percent lean	.08	Woodward *et al*. (1959). 180 day weaning weight.
Percent fat	.12	Woodward *et al*. (1959). 180 day weaning weight.
Percent bone	-.14	Woodward *et al*. (1959). 180 day weaning weight.

The correlations reported indicate that weaning weight has more predictive value than does birth weight for certain carcass traits. The correlations indicate weaning weight to be more indicative of future size and growth than of future carcass quality. The trend of the correlations between birth weight and carcass grade was negative but weaning weight tended to be positively correlated with carcass grade. Weaning weight was also more strongly correlated with measures of carcass lean such as area of rib-eye and percent separable lean in the 9-10-11th rib section. The literature reviewed indicates that weaning weight is more predictive of future growth and carcass traits than is birth weight.

TABLE III. PHENOTYPIC CORRELATIONS BETWEEN FINAL WEIGHT AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Authors and remarks
Carcass grade	.54	Knapp and Nordskog (1946). This study was done at the Miles City Station and involved 177 steer calves. They were all slaughtered at the end of the feed trial after being shipped to South St. Paul or Chicago.
	.40	Woodward *et al*. (1954).

TABLE III. (Continued)

Slaughter or carcass trait	r	Authors and remarks
Carcass grade (Continued)	.52	Magee et al. (1958). This study involved steers from two different sources. The total number involved was 104. They were slaughtered at the end of time constant feeding periods.
	.21	Woodward et al. (1959).
	.36	Blackwell et al. (1962).
	.52	Matthews and Bennett (1962). This study involved a total of 24 steers and heifers and utilized varying feed rations. It was designed primarily to study the effect of rate of gain on carcass traits. The cattle were slaughtered after a time-constant feeding period. Carcass weight, a function of final weight, was correlated with various carcass measures and these values are reported here.
	.49	Neville et al. (1962). This experiment was conducted in Georgia and involved 98 steers and heifers. The cattle were fattened on experimental rations on winter pasture of oats and ryegrass for 132 days.
	.35	Shelby et al. (1963).
	.16	Swiger et al. (1965).
	.09	Dubose et al. (1967).
Carcass weight	.95	Blackwell et al. (1962).
	.93	Neville et al. (1962).
	.96	Shelby et al. (1963).
	.86	Dubose et al. (1967).
Dressing percent	.25	Woodward et al. (1954).
	.03	Woodward et al. (1959).
	.26	Blackwell et al. (1962).
	.54	Matthews and Bennett (1962). Carcass weight x dressing percent.
	.19	Shelby et al. (1963).
Rib-eye area	.14	Knapp and Nordskog (1946).
	.44	Woodward et al. (1954).

TABLE III. (Continued)

Slaughter or carcass trait	r	Authors and remarks
Rib-eye area (Continued)	.38	Orme et al. (1959a). This study was composed of 8 Angus and 23 Hereford steers. They apparently were not slaughtered after a time constant feed period but the authors did not report what the slaughter conditions were, ie., weight or grade-constant.
	.20	Woodward et al. (1959).
	.64	Matthews and Bennett (1962). Carcass weight x rib-eye area.
	.02	Matthews and Bennett (1962). Carcass weight x rib-eye area/100 pounds carcass weight.
	.41	Shelby et al. (1963).
	.31	Dubose et al. (1967).
	.75	Abraham et al. (1968). This study examined the relationships between carcass weight and measures of carcass merit. The carcass measurements were taken as described by Orts (1962). This study involved 835 steers of several breeds and crossbreeds from varying sources and slaughter conditions.
Length of leg	.70	Woodward et al. (1954).
	.71	Woodward et al. (1959).
	.70	Shelby et al. (1963).
	.54	Dubose et al. (1967).
	.67	Abraham et al. (1968). Carcass weight x length of leg.
Length of loin	.49	Birkett et al. (1965). This study involved 32 steers killed as a group. The carcasses ranged from 498 to 749 pounds. The steers were about 18 months old when slaughtered and were all Herefords. Carcass measurements were taken as described by Naumann (1952).
Cutability	-.21	Swiger et al. (1965).
	-.52	Birkett et al. (1965). Carcass weight x percent trimmed round, loin, rib, and chuck.

TABLE III. (Continued)

Slaughter or carcass trait	r	Authors and remarks
Marbling score	.58	Matthews and Bennett (1962). Carcass weight x marbling score.
Shear force	.10	Woodward et al. (1959).
	.34	Matthews and Bennett (1962). Carcass weight x shear force.
Percent lean	-.06	Woodward et al. (1959). 9-10-11th rib separation.
	-.28	Brackelsburg and Willham (1968). This study involved 51 bulls, steers and heifers killed at the end of a 168-day feed trial. Percent lean, fat and bone estimates were made following separations of the entire carcass. Correlations are with carcass weight.
Percent fat	.30	Woodward et al. (1959). 9-10-11th rib separation.
	.18	Brackelsburg and Willham (1968). Carcass weight.
Percent bone	-.31	Woodward et al. (1959). 9-10-11th rib separation.
	-.33	Brackelsburg and Willham (1968). Carcass weight.
Fat thickness	.33	Woodward et al. (1954).
	.33	Woodward et al. (1959).
	.31	Shelby et al. (1963).
	.27	Swiger et al. (1965).
	.13	Dubose et al. (1967).
	.34	Matthews and Bennett (1962). Carcass weight x fat thickness.
	.01	Matthews and Bennett (1962). Carcass weight x fat thickness/100 pounds carcass weight.
	.60	Abraham et al. (1968). Carcass weight x average fat thickness.
	.47	Abraham et al. (1968). Carcass weight x single fat thickness.

TABLE III. (Continued)

Slaughter or carcass trait	r	Authors and remarks
Width of round	.80	Orme et al. (1959). The animals used in this study were the same ones used in the study by Orme et al. (1959a). Carcass measurements were taken on the unsplit carcass.
	.55	Woodward et al. (1959).
	.32	Dubose et al. (1967).
	.74	Abraham et al. (1968). Carcass weight x width of round.
Circumference of round	.44	Orme et al. (1959). Unsplit carcass.
	.56	Woodward et al. (1959).
Width of shoulder	.79	Orme et al. (1959). Unsplit carcass.
	.68	Woodward et al. (1959).
Depth of body	.67	Orme et al. (1959). Unsplit carcass.
	.48	Woodward et al. (1959). Measured at 7th rib.
Length of body	.78	Woodward et al. (1954).
	.66	Orme et al. (1959). Unsplit carcass.
	.68	Woodward et al. (1959).
	.76	Shelby et al. (1963).
	.79	Dubose et al. (1967).
	.80	Abraham et al. (1968). Carcass weight x length of body.

TABLE IV. PHENOTYPIC CORRELATIONS BETWEEN AVERAGE DAILY GAIN ON FEED AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Author and remarks
Slaughter weight	.53	Lindholm and Stonaker (1957).
	.89	Woodward *et al.* (1959).
	.19	Neville *et al.* (1962).
	.81	Shelby *et al.* (1963).
	.86	Swiger *et al.* (1965).
	.66	Dubose *et al.* (1967).
Slaughter age	-.16	Lindholm and Stonaker (1957). This was expressed as "days on feed x slaughter age" and is not a true picture of the relationship between daily gain and slaughter age. It actually says that older animals required fewer days on feed to reach a live grade of Low Choice than did younger animals.
Carcass grade	.37	Hankins and Burk (1932). This study involved 2,073 cattle from experiment stations in 18 states. It contained both steers and heifers from varying environments.
	.25	Durham and Knox (1953). This study involved 59 steers which were fed for 196 days prior to slaughter.
	.08	Yao *et al.* (1953).
	.40	Woodward *et al.* (1954).
	-.31	Cartwright *et al.* (1958). This study involved 18 Hereford and 20 Brahman x Hereford steers randomly assorted to two feed rations. The correlations are pooled for breeds and rations. The negative relationship with carcass grade actually indicates a favorable relationship since a decreasing numerical score indicates an increase in carcass quality grade.
	.43	Magee *et al.* (1958).
	.31	Carter and Kincaid (1959).
	.27	Woodward *et al.* (1959).
	.43	Blackwell *et al.* (1962).
	-.05	Brown *et al.* (1962).
	.24	Neville *et al.* (1962).
	.37	Shelby *et al.* (1963).
	.17	Swiger *et al.* (1965).

TABLE IV. (Continued)

Slaughter or carcass trait	r	Author and remarks
Carcass grade (Continued)	.17	Dubose *et al*. (1967).
Carcass weight	.51	Cartwright *et al*. (1958).
	.72	Blackwell *et al*. (1962).
	.19	Neville *et al*. (1962).
	.81	Shelby *et al*. (1963).
	.59	Dubose *et al*. (1967).
Dressing percent	-.32	Stroble *et al*. (1951). This study involved 75 cattle slaughtered at a constant weight of 900 pounds.
	-.09	Yao *et al*. (1953).
	.11	Woodward *et al*. (1954).
	-.05	Woodward *et al*. (1959).
	.26	Blackwell *et al*. (1962).
	.27	Brown *et al*. (1962).
	.10	Shelby *et al*. (1963).
Rib-eye area	.33	Woodward *et al*. (1954). The authors calculated the partial correlation holding final weight constant and found this correlation dropped to zero.
	.39	Cartwright *et al*. (1958).
	.15	Woodward *et al*. (1959).
	.72	Brown *et al*. (1962).
	-.04	Neville *et al*. (1962). This correlation was between daily gain and rib-eye area/100 pound carcass.
	.36	Shelby *et al*. (1963).
	.23	Dubose *et al*. (1967).
Fat thickness	.33	Woodward *et al*. (1954). The partial correlation holding final weight constant was -.21.
	.26	Cartwright *et al*. (1958).
	.29	Woodward *et al*. (1959).
	.30	Shelby *et al*. (1963).
	.25	Swiger *et al*. (1965).
	.06	Dubose *et al*. (1967).

TABLE IV. (Continued)

Slaughter or carcass trait	r	Author and remarks
Width of round	.47	Woodward et al. (1959).
	.31	Dubose et al. (1967).
Circumference of round	.54	Woodward et al. (1959).
Width of shoulder	.65	Woodward et al. (1959).
Depth of body	.40	Woodward et al. (1959). Measured at 7th rib.
Length of body	.57	Woodward et al. (1954). Partial correlation holding final weight constant was -.03.
	.54	Woodward et al. (1959).
	.60	Shelby et al. (1963).
	.61	Dubose et al. (1967).
Length of leg	.49	Woodward et al. (1954). Partial correlation holding final weight constant was -.09.
	.55	Woodward et al. (1959).
	.56	Shelby et al. (1963).
	.46	Dubose et al. (1967).
Plumpness index	.22	Woodward et al. (1959).
Cutability	-.16	Swiger et al. (1965).
Marbling score	.20	Cartwright et al. (1958).
Shear force		Marion et al. (1949) reported higher gaining steers produced more tender meat than lower gaining ones. The sample size was small in this study.
	.09	Woodward et al. (1959).
	.14	Brown et al. (1962).
		Matthews and Bennett (1962) found no signifi-

TABLE IV. (Continued)

Slaughter or carcass trait	r	Author and remarks
Shear force (Continued)		cant relationship between rate of gain and tenderness as measured organoleptically or with the Warner-Bratzler shear.
	-.15	Suess *et al.* (1966). This study involved 128 Angus steer and heifer progeny from six different herds.
Percent lean	-.24	Cartwright *et al.* (1958).
	-.15	Woodward *et al.* (1959).
Percent fat	.30	Cartwright *et al.* (1958).
	.34	Woodward *et al.* (1959).
	.11	Brown *et al.* (1962). Chemical analysis.
Percent bone	-.33	Woodward *et al.* (1959).

TABLE V. PHENOTYPIC CORRELATIONS BETWEEN GAIN PER DAY OF AGE AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Author and remarks
Slaughter weight	.86	Neville et al. (1962). Wt./day of age at slaughter.
Carcass grade	-.34	Cartwright et al. (1958). Gain to 180 days x carcass grade. (Decreasing score = increasing grade).
	-.35	Cartwright et al. (1958). Wt./day of age at end of test x carcass grade.
	.39	Neville et al. (1962). Wt./day of age at slaughter x carcass grade.
Carcass weight	.81	Cartwright et al. (1958). Gain to 180 days x carcass weight.
	.79	Cartwright et al. (1958). Wt./day of age at end of test x carcass weight.
	.77	Neville et al. (1962). Wt./day of age at slaughter x carcass weight.
Rib-eye area	.31	Cartwright et al. (1958). Gain to 180 days x rib-eye area.
	.38	Cartwright et al. (1958). Wt./day of age at end of test x rib-eye area.
	-.57	Cartwright et al. (1958). Gain to 180 days x rib-eye area/100 lbs. carcass wt.
	-.46	Cartwright et al. (1958). Wt./day of age at end of test x rib-eye area/100 lbs. carcass wt.
	-.34	Neville et al. (1962). Wt./day of age at slaughter x rib-eye area/100 lbs. carcass wt.
Fat thickness	.56	Cartwright et al. (1958). Gain to 180 days x fat thickness.
	.50	Cartwright et al. (1958). Wt./day of age at end of test x fat thickness.
Marbling score	.30	Cartwright et al. (1957). Gain to 180 days x estimated percent marbling.

TABLE V. (Continued)

Slaughter or carcass trait	r	Author and remarks
Marbling score (Continued)	.36	Cartwright *et al.* (1958). Wt./day of age at end of test x estimated percent marbling.
Shear force	.01	Suess *et al.* (1966). Wt./day of age at slaughter x shear force.
Percent lean	-.56	Cartwright *et al.* (1958). Gain to 180 days x percent lean in 9-10-11th rib section.
	-.45	Cartwright *et al.* (1958). Wt./day of age at end of test x percent lean in 9-10-11th rib section.
Percent fat	.59	Cartwright *et al.* (1958). Gain to 180 days x percent fat in 9-10-11th rib section.
	.52	Cartwright *et al.* (1958). Wt./day of age at end of feed test x percent fat in 9-10-11th rib section.

The phenotypic correlations reported concerning final weight and average daily gain as they are related to various measures of carcass quality, indicate they are of considerably higher predictive value than is birth weight or weaning weight.

If both final weight and average daily gain are available as selection tools it appears that final weight has somewhat more value in predicting carcass quality than does average daily gain. The magnitude of the correlations reported indicate final weight is more predictive than average daily gain of carcass grade, rib-eye area, fat thickness, most linear measurements (width, circumference and length), marbling score and shear force. These are characteristics which are all quite important in determining overall carcass quality and composition. It should be pointed out however, that the differences in the magnitudes of the correlations produced by these two traits is not great in any instance.

Gain or weight per day-of-age did not appear to be of any more value than either final weight or average daily gain as a selection tool in beef carcass improvement. They did appear, from the articles reviewed, to be somewhat more strongly related to fat content of the 9-10-11th rib section, both from the standpoint of fat thickness and percent fat. Many of the correlations quoted involved weight per day of age and it must be recognized that this value is influenced by birth weight where gain per day of age is not.

Genetic Correlations

A review is also presented of the genetic correlations reported between production and carcass traits. The present study includes calculation of correlation and regression values between the production traits of sires and the means of the carcass traits of their respective progeny. Although it is recognized that these correlations are not actually true genetic correlations since measurements of both production and carcass traits were not available on both sire and progeny, it was felt that the nearness of these values to true genetic correlations warranted this review.

Tables VI, VII, VIII, IX and X present genetic correlations reported between various carcass traits and birth weight, weaning weight (actual and adjusted 180-day), average daily gain, final weight and gain per day of age.

TABLE VI. GENETIC CORRELATIONS BETWEEN BIRTH WEIGHT AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Author and remarks
Slaughter weight	.51	Shelby *et al*. (1963). This study involves 616 steers slaughtered after a feed period of 252 days. The experiment was done at the U. S. Range Livestock Experiment Station at Miles City, Montana.
Yearling weight	.40	Koch and Clark (1955). This study involved comparisons of 1694 Hereford cattle at the Miles City, Montana Station. The data were adjusted to a heifer basis. This was the yearling weight and not the final or slaughter weight.
	.56	Brinks *et al*. (1964). All the animals used in this study were females. The study involves records on over 3500 females from the Miles City Experiment Station.
Final weight	.75	Brinks *et al*. (1962). This study involved 1029 bulls performance tested at Miles City, Montana. This correlation is between birth weight and final weight at the end of a 196 day feed trial.
Carcass grade	-.43	Shelby *et al*. (1963).
Carcass weight	.39	Shelby *et al*. (1963).
Dressing percent	-.25	Shelby *et al*. (1963).
Area of rib-eye	-.01	Shelby *et al*. (1963).
Fat thickness	-.16	Shelby *et al*. (1963).
Length of body	.30	Shelby *et al*. (1963).
Length of leg	.66	Shelby *et al*. (1963).

TABLE VII. GENETIC CORRELATIONS BETWEEN WEANLING TRAITS AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Author and remarks
Yearling weight	.54	Koch and Clark (1955). 182-day weaning weight.
	.71	Brinks et al. (1964). Trial involved only females.
Final weight	.67	Brinks et al. (1962). 180-day weaning weight x final weight at end of 196 day feed test.
Slaughter weight	.89	Shelby et al. (1963). 180-day weaning weight.
Yearling weight	.31	Koch and Clark (1955). Weaning score x yearling weight.
Carcass grade	.84	Carter and Kincaid (1959). Weaning weight was expressed as 182-day weight. The study involves 195 steers fed for 200 days and slaughtered.
	.92	Blackwell et al. (1962). This study involved data from 421 steers killed at the end of a 168 day fattening period. The steers were approximately 2 years old at slaughter.
	-.04	Shelby et al. (1963). 180-day weaning weight.
	-.43	Swiger et al. (1945). Involves 480 steers, bulls and heifers slaughtered after a time-constant feed period. Includes both straight-bred and crossbred cattle.
Carcass weight	1.10	Blackwell et al. (1962).
	.90	Shelby et al. (1963). 180-day weaning weight.
Dressing percent	1.56	Blackwell et al. (1962).
	.30	Shelby et al. (1963). 180-day weaning weight.
Area of rib-eye	.40	Shelby et al. (1963). 180-day weaning weight.
Fat thickness	.91	Shelby et al. (1963). 180-day weaning weight.
	-.29	Swiger et al. (1965).

TABLE VII. (Continued)

Slaughter or carcass trait	r	Author and remarks
Length of body	.81	Shelby *et al*. (1963). 180-day weaning weight.
Length of leg	.92	Shelby *et al*. (1963). 180-day weaning weight.
Percent retail prod. (cutability)	.09	Swiger *et al*. (1965). This was expressed as percent of boneless closely trimmed retail cuts.

TABLE VIII. GENETIC CORRELATIONS BETWEEN AVERAGE DAILY GAIN AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Author and remarks
Yearling weight	.83	Koch and Clark (1955). Gain wean to yearling x yearling weight.
Slaughter weight	.91	Shelby _et al._ (1963).
Carcass grade	.85	Carter and Kincaid (1959).
	.78	Blackwell _et al._ (1962).
	.25	Shelby _et al._ (1963).
	.08	Swiger _et al._ (1965).
Carcass weight	.98	Blackwell _et al._ (1962).
	.90	Shelby _et al._ (1963).
Dressing percent	.94	Blackwell _et al._ (1962).
	.01	Shelby _et al._ (1963).
Area of rib-eye	-.10	Shelby _et al._ (1963).
Fat thickness	.14	Shelby _et al._ (1963).
	.49	Swiger _et al._ (1965).
Length of body	.85	Shelby _et al._ (1963).
Length of leg	.87	Shelby _et al._ (1963).
Cutability	-.45	Swiger _et al._ (1965). This correlation was between daily gain x percent retail product.

TABLE IX. GENETIC CORRELATIONS BETWEEN FINAL WEIGHT AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Author and remarks
Slaughter weight	.98	Shelby et al. (1963).
Carcass grade	.88	Blackwell et al. (1962).
	.12	Shelby et al. (1963).
	-.14	Swiger et al. (1965).
Carcass weight	1.15	Blackwell et al. (1962).
	.95	Shelby et al. (1963).
	.70	Levi et al. (1967). This study included 525 Israel-Friesian bull calves between 12 and 16 months of age. Feeding methods varied since these were all slaughter house cattle from 46 different farms.
Dressing percent	1.41	Blackwell et al. (1962).
	.04	Shelby et al. (1963).
	-.13	Levi et al. (1967).
Area of rib-eye	.03	Shelby et al. (1963).
Fat thickness	.29	Shelby et al. (1963).
	.18	Swiger et al. (1965).
Length of body	.87	Shelby et al. (1963).
Length of leg	.88	Shelby et al. (1963).
Cutability	-.25	Swiger et al. (1965).
Percent fat	.68	Levi et al. (1967). This was expressed as non-saleable fat and was estimated from ruminal fat.

TABLE X. GENETIC CORRELATIONS BETWEEN GAIN PER DAY OF AGE AND SLAUGHTER OR CARCASS TRAITS.

Slaughter or carcass trait	r	Author and remarks
Yearling weight	.51	Koch and Clark (1955). Gain birth to weaning x yearling weight.
	.67	Brinks *et al.* (1964). Gain to weaning x yearling weight using females.
Final weight	.54	Brinks *et al.* (1962). 180-day gain x final weight at end of feed test.
	.76	Brinks *et al.* (1962). 196-day gain x final weight at end of feed test.
Carcass grade	.47	Cundiff *et al.* (1964). This correlation was calculated between carcass weight/day of age x carcass grade. The study involved 265 Hereford and Angus steers fed at Ft. Reno, Oklahoma.
Dressing percent	-.44	Levi *et al.* (1967).
Percent fat	.43	Levi *et al.* (1967). Expressed as non-saleable fat.
Percent retail cuts	.02	Cundiff *et al.* (1964). Carcass weight/day of age x percent retail cuts as determined by use of the regression equation presented by Murphey *et al.* (1960).

Upon examination of the genetic correlations reviewed, it again appears that birth weight is of little predictive value as far as carcass quality factors are concerned and is indicative only of overall size and scale. All the production measures reviewed were, in general fairly indicative of overall carcass size factors such as weight measurements and length measurements. However, widely varying values were reported between production traits and carcass quality factors such as carcass grade, rib-eye area, fat thickness and cutability. Average daily gain was the only production trait which was correlated positively with carcass grade by all the workers who studied it. Area of rib-eye seems to be slightly positively correlated genetically with growth traits as does fat thickness, although some negative values were reported concerning both relationships. Cutability appears to be somewhat negatively correlated with growth measurements, although it is recognized that the relationship was studied almost entirely by only one group of workers (Swiger _et al._, 1965).

As with the phenotypic correlations it appears that growth records are reasonably good indicators of genetic potential for size and growth but that, as the contrasting correlations indicate, their relationships with quality factors are still vague and in need of further study.

Heritability Estimates

A review of heritability estimates for birth weight, actual weaning weight, 180-day adjusted weaning weight, average daily gain on feed test, final weight, and gain per day of age at weaning are presented in Table XI. It becomes apparent upon examination of the literature that there are far more estimates made from the paternal half-sib method than from the method

TABLE XI. HERITABILITY ESTIMATES REPORTED FOR VARIOUS PRODUCTION TRAITS.

Author and Method of Analysis	Birth weight	Weaning weight	180-day weight	Av. daily gain	Final weight	Gain/day at weaning	Comments
Sire-offspring method							
Koch and Clark (1955b)	.35	.25				.17	
Rollins and Wagnon (1956)		.30					Offspring on dam regression X 2.
Kincaid and Carter (1958)				.38			Estimate for bulls.
Paternal half-sib method							
Dawson *et al.* (1946)	.29						
Gregory *et al.* (1950)	.45		.26			.00	Trial contained small numbers.
	1.00		.52			.45	
Knapp and Clark (1950)	.53		.28	.65	.86		
Burris and Blumm (1952)	.22						
Dawson *et al.* (1954)			.19				
Dawson *et al.* (1955)	.51			.19			Also found an estimate of .45 for days to weaning at 500 lbs.
Koch and Clark (1955a)	.35	.24		.39	.47	.21	Final weight = yearling weight.
Shelby *et al.* (1955)	.72		.23	.60	.84		
Shelby *et al.* (1960)				.46	.77		Trial involved bulls.
Swiger (1961)	.22	.25		.40	.47		
Blackwell *et al.* (1962)		.31			.71		Final weight = yearling weight.
Brinks *et al.* (1962)				.40	.48		
Swiger *et al.* (1962)	.30					.14	
	.37					-.02	
Shelby *et al.* (1963)	.54		.24	.48	.64		
Brinks *et al.* (1964	.38		.43			.40	Experiment involved females.
Pahnish *et al.* (1964)	.32	.05				.01	
Cunningham and Henderson (1965)						.47	= Angus.
						.43	= Herefords.
Marlowe and Vogt (1965)						.43	= Angus.
						.27	= Herefords.
Minyard and Dinkel (1965)			.32				190-day weaning weight.
Levi *et al.* (1967)						.92	Gain/day of age at slaughter.

utilizing the regression of offspring on parent. In most cases, this is probably due to availability of necessary information since records on performance of sires have been unobtainable in many cases.

EXPERIMENTAL METHODS AND PROCEDURES

This study utilized 15 years of data from the cattle records of the North Montana Branch Experiment Station at Havre, Montana for the period 1952-1966, inclusive. All the steers in the study are crossline Hereford steers of lines 5, 6, and 7. Flower et al. (1963) has described the breeding program at the North Montana Branch Station. All the steers are out of line 4 cows and were sired by bulls from line 1, 2 or 3. There are no line 4 steers included in the study. Flower et al. (1963) and Anderson (1966) have described the management of the cattle at the Station, the range conditions on the Station and the weather conditions.

Only records on animals which went directly into the feedlot on a fattening ration immediately following weaning were included in the study. Records on any animal which exhibited sickness or abnormalities which might affect its performance or carcass quality were removed. Care was also taken to insure that complete records of all traits studied were available for all animals included in the study.

The cattle management was similar during each of the 15 years included in the study. Calves were born at the Station under close supervision and birth weights were recorded within six hours after birth. All calves were tattooed and ear-tagged for identification when weighed.

Weaning weights and scores were taken between October 1 and October 15 at the mountain lease with the calves then being trucked to the main Station and put in the feedlot.

Flower et al. (1963) described the feeding and selection procedures practiced on the bull calves. All the bulls were individually fed for 168 days during the entire 15 years of the study. Anderson (1966) described the weighing procedures.

The steer calves were vaccinated for shipping fever upon arrival at the main Station from the mountain lease and put on a 2-3 week warm-up ration. Flower et al. (1963) has described the lotting and feeding of the steers. During the period 1952-1959 the steers were all slaughtered after a time constant feeding period. The length of the feeding period varied from 196 days in the earlier years to 224 days in 1959. However, it was not felt that this difference would significantly affect the results since year differences were removed and the period 1952-1959 was analyzed as one type of feeding regime. Since 1959 the steers have been slaughtered on a relatively weight-constant basis. They were marketed upon reaching a live weight of 1050 pounds or when they reached a live grade of choice prior to this weight. The steers were weighed every 28 days and those meeting these requirements at that time were marketed. Consequently, some steers weighed over 1050 pounds at slaughter. A few weighed 1100 pounds or more. Also, at various times changes in slaughter had to be made depending on the handling capabilities of the processing plant.

A phenotypic correlation study is presented in which eight production traits of 339 crossline Hereford steers were correlated with 27 of their own slaughter and carcass traits by use of simple correlation and regression analyses.

A sire-offspring study is presented utilizing data from 78 sires and their progeny groups. Ten production characteristics of the sires were related to 27 slaughter and carcass traits of their steer progeny by use of simple correlation and regression analyses.

Table XII shows the degrees of freedom associated with the two time periods. Since not all the carcass traits were recorded during all 15 years of the study, the degrees of freedom vary within each time period according to the carcass traits involved.

TABLE XII. DEGREES OF FREEDOM BY TIME PERIODS FOR PHENOTYPIC CORRELATION STUDY AND SIRE-OFFSPRING STUDY.

y Variables	Period	No. of Observations	Years	d.f.
	Phenotypic correlation study			
1-22	1	159	8	151
1-22	2	180	7	173
23	1	88	4	84
23	2	180	7	173
24-27	1	13	1	12
24-27	2	134	7	127
	Sire-offspring study			
1-22	1	38	8	30
1-22	2	40	7	33
23	1	20	4	16
23	2	40	7	33
24-27	1	5	1	4
24-27	2	38	7	31

Six production traits common to both the sires and the steer progeny were also analyzed by simple correlation and regression analyses to obtain heritability estimates for these traits.

The data were first analyzed by years for the 15-year period. The intra-year sums of squares and sums of crossproducts for each time period, 1952-1959 (period 1) and 1960-66 (period 2) were then pooled. From these values, correlation and regression coefficients for each time period were calculated. Since these were the corrected sums of squares and cross-products by years, the pooled values were corrected for year effects.

The phenotypic correlation study involves 339 steers. The eight growth and production traits used were:

1. Birth weight, pounds.
2. Actual weaning weight, pounds.
3. Weaning age, days.
4. Adjusted 180-day weight, pounds. Adjusted to 180 days using the calf's own preweaning daily gain.
5. Final weight (essentially slaughter weight), pounds.
6. Average daily gain on feed, pounds.
7. Preweaning daily gain, pounds.
8. Gain per day of age at slaughter, pounds.

The slaughter or carcass traits were considered the dependent variables and were:

1. Slaughter weight, pounds.
2. Age at slaughter, days.
3. Carcass grade. This is the official U.S.D.A. quality grade. (19 = Low Choice, 18 = High Good, etc.)
4. Cold carcass weight, pounds.
5. Dressing percent. (cold carcass weight ÷ slaughter weight) X 100.
6. Area of rib-eye, square inches.
7. Fat thickness, in hundredths of an inch. This is a single fat thickness measurement taken 3/4 of the length of the rib-eye from the backbone and perpendicular to the surface of the fat.
8. Average fat thickness, mm. Three measurements taken 1/4, 1/2, and 3/4 the distance of the long axis of the rib-eye and

perpendicular to the fat surface.

9. Area of rib-eye per 100 pounds of carcass weight, square inches.
10. Fat thickness per 100 pounds of carcass weight. This is number 7 divided by carcass weight.
11. Length of rib-eye, mm. The length of the longest axis of the rib-eye.
12. Width of rib-eye, mm. Average of three measurements made 1/4, 1/2 and 3/4 the length of the rib-eye and perpendicular to the long axis.
13. Rib-eye index. (length of rib-eye $\div$ width of rib-eye) X 100.
14. Width of round, mm.
15. Width of shoulder, mm.
16. Depth of body, mm.
17. Circumference of round, mm.
18. Length of body, mm.
19. Length of hind leg, mm.
20. Length of loin, mm.
21. Plumpness index. (circumference of round $\div$ length of hind leg) X 100.
22. Estimated lean yield. This is the cutability estimate calculated either with the U.S.D.A. Yield Grade Finder or from the regression equation: lean yield = 51.34 - 5.784 (one fat thickness in hundredths of an inch) - .0093 (hot carcass weight) - .462 (% kidney fat) + .74 (area of rib-eye).
23. Marbling score. 10 = abundant.....1 = devoid.

24. Shear force, pounds. Average shear force of five ½ inch cores sheared on a Warner-Bratzler shear taken from the 12th rib _l. dorsi_ steak, cooked to an internal temperature of 170° F.

25. Percent separable lean. This is the knife separable lean of the 12th rib section.

26. Percent separable fat. Knife separable fat of the 12th rib section.

27. Percent separable bone. Knife separable bone of the 12th rib section.

The linear measurements were taken by the methods described by Naumann (1952). Carcass traits 1-22 were recorded in all 15 years of the study. Recording of trait 23, marbling score, was begun in 1956 and traits 24-27 were recorded from 1959 through 1966.

The sire-offspring study involved 78 progeny groups. The ten independent variables studied were:

1. Wright's coefficient of inbreeding of the sire.
2. Birth weight, pounds.
3. Weaning weight, pounds.
4. Weaning age, days.
5. 180-day adjusted weaning weight, pounds.
6. Weaning score.
7. Final weight, pounds.
8. Average daily gain, pounds.
9. Score at end of feed test.
10. Gain per day at weaning, pounds.

These ten variables on the 78 sires were related to their steer progeny means for the 27 carcass and slaughter variables described previously. Each sire's production traits were expressed as a deviation from the respective mean of the contemporary sire groups in which they were born, weaned and fed. The primary effect of this procedure was to remove year effect associated with the sires. The method used to arrive at the sire values for each trait was $T - T' + K$, where T equals the sire's own measurement for a particular trait, T' equals the contemporary mean for that trait, and K equals a constant added to eliminate negative numbers. The value of K for each trait was the mean of the year means for that trait for each of the 15 years of the study. This formula was used for variables 2-10. The coefficient of inbreeding was expressed as an actual value for each sire and not as a deviation.

The 27 carcass traits were each expressed as means of progeny groups. Some sires were used in two or more years. In such instances, the progeny groups in different years were analyzed separately. As in the phenotypic correlation study, the data were analyzed within years. The intra-year sums of squares and sums of crossproducts were then pooled for the two time periods, 1952-1959 and 1960-1966. The correlation and regression values obtained in this manner for the two time periods were corrected for year effects within period.

Heritability estimates were obtained for birth weight, weaning weight, 180-day adjusted weaning weight, final weight, average daily gain and daily gain from birth to weaning. These estimates were obtained by doubling the sire-offspring regression for each trait.

RESULTS AND DISCUSSION

For discussion purposes, the correlations were divided into two general categories: (1) those involving measurements such as weights and linear carcass measurements which are more associated with overall size and scale, and (2) those concerned with quality factors such as grade, rib-eye area, percentages, etc.

Phenotypic Correlations

Table XIII shows the phenotypic correlation and regression values obtained between the eight production traits and certain weight and linear carcass measurements as well as with slaughter age.

It can first be noted that the correlations are considerably stronger in most all cases during period 1. The values reported between growth traits and measures of carcass size are significant at least at the 5 percent level. Those animals which were heavier at earlier periods would generally tend to be heavier and thus larger in weight and linear carcass measurements after a time constant feeding period. The magnitudes of the correlations obtained in this portion of the study agree with those of numerous previous investigators, (Lush, 1932; Woodward *et al.*, 1954; Woodward *et al.*, 1959; Blackwell *et al.*, 1962; Shelby *et al.*, 1963; Dubose *et al.*, 1967).

The general low trend of the correlations in period 2 would indicate that animals slaughtered at the same weight tend to have the same general body measurements. If all the animals in this period had been slaughtered at exactly the same weight, most of the correlations would probably approach zero. Those involving final weight would be zero since the sums of squares for X (independent variable) and the sums of crossproducts

TABLE XIII. SIMPLE CORRELATION AND REGRESSION COEFFICIENTS BETWEEN PRODUCTION TRAITS AND VARIOUS WEIGHT, AGE AND LINEAR CARCASS MEASUREMENTS OF 339 CROSSLINE HEREFORD STEERS.

		Slaughter Trait (y)										
Production Trait (X)		Slaughter weight	Slaughter age	Carcass weight	Width round	Width shoulder	Depth body	Circumference round	Length body	Length leg	Length loin	Plumpness index
Birth weight 1/	r	.45**	-.03	.45**	.25**	.29**	.23**	.34**	.39**	.38**	.32**	.01
	b	3.67	-.06	2.31	.94	.52	.33	1.37	1.64	2.12	.85	.01
2/	r	.21**	-.36**	.14	.13	-.03	.06	.07	.06	.22**	.10	-.11
	b	1.04	-.96	.41	.22	-.11	.08	.22	.24	.41	.19	-.06
Weaning weight	r	.76**	.57**	.80**	.36**	.51**	.52**	.52**	.68**	.35**	.58**	.03
	b	.94	.16	.62	.21	.14	.12	.31	.43	.29	.23	.002
	r	.37**	-.28**	.36**	.20**	.17*	.21**	-.02	-.03	.28**	.25**	-.21**
	b	.26	-.11	.15	.05	.08	.04	-.01	-.02	.08	.07	-.02
Weaning age	r	.32**	.99**	.37**	.20**	.31**	.31**	.18*	.25**	.18*	.24**	-.01
	b	1.43	1.00	1.01	.40	.30	.25	.39	.56	.54	.34	-.002
	r	.12	.27**	.13	.02	.13	.20**	-.07	-.10	.13	.10	-.13
	b	.34	.42	.22	.02	.24	.16	-.13	-.21	.14	.12	-.05
180-day weight	r	.70**	.04	.73**	.31**	.41**	.43**	.50**	.66**	.30**	.55**	.04
	b	1.09	.01	.71	.22	.14	.12	.38	.52	.32	.27	.004
	r	.39**	-.50**	.36**	.24**	.13	.14	.02	.04	.27**	.24**	-.18*
	b	.34	-.23	.19	.07	.07	.03	.0114	.02	.09	.08	-.02
Final weight 1/	r	.99**	.36**	.96**	.44**	.69**	.47**	.63**	.87**	.37**	.74**	.05
	b	.96	.08	.59	.20	.15	.08	.30	.43	.24	.23	.004
2/	r	1.00**	-.22**	.84**	.40**	.29**	.19*	.34**	.39**	.46**	.34**	-.02
	b	.96	-.11	.49	.13	.19	.05	.22	.28	.17	.13	-.002
Avg. daily gain	r	.66**	-.15	.56**	.27**	.44**	.17*	.36**	.55**	.19*	.50**	.003
	b	219.73	-11.05	117.81	41.19	32.54	10.24	58.83	94.36	43.81	54.17	.06
	r	.65**	-.57**	.40**	.26**	.21**	-.04	.21**	.12	.21**	.18*	.001
	b	128.16	-60.24	47.52	17.51	27.17	-1.98	27.68	18.03	15.15	13.51	.03

1/ = Period 1
2/ = Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
* = P <.05
** = P <.01

TABLE XIII. (Continued)

		Slaughter Trait (y)										
		Slaughter weight	Slaughter age	Carcass weight	Width round	Width shoulder	Depth body	Circumfer-ence round	Length body	Length leg	Length loin	Plumpness index
Gain/day @ wean	r	.66**	.05	.68**	.28**	.38**	.41**	.46**	.62**	.25**	.52**	.03
	b	195.70	3.05	127.31	37.73	24.54	22.09	67.46	94.61	42.29	49.79	.69
	r	.36**	-.44**	.35**	.22**	.15	.14	.01	.02	.24**	.25**	-.16*
	b	59.09	-38.81	34.25	12.27	15.71	5.95	.85	2.17	14.80	15.7416	-3.16
Gain/day @ sl.	r	.89**	-.13	.81**	.35**	.55**	.33**	.55**	.78**	.27**	.68**	.05
	b	402.95	-13.40	232.22	74.08	54.78	26.79	122.47	181.73	81.97	100.45	1.47
	r	.77**	-.78**	.56**	.37**	.26**	.05	.18*	.10	.33**	.26**	-.10
	b	220.83	-121.50	97.61	36.74	48.79	3.62	34.08	22.17	35.48	29.44	-3.48

r = Correlation coefficient
b = Regression coefficient of y on x
* = $P < .05$
** = $P < .01$

would be zero. The correlations involving the other growth traits would also be reduced since holding final weight constant reduces the variability in the carcass traits.

Also of interest are the highly significant ($P < .01$) negative correlations existing between all the growth traits and slaughter age in period 2. These would indicate that when feeding cattle to a constant weight, selection for rapid gain to slaughter can be made from records as early as birth weight. The values and trends reported support those found by Yao et al. (1953) and Christian et al. (1965). The regression of slaughter age on birth weight indicates a decrease of 0.96 days in age at slaughter at 1050 pounds for each one pound increase in birth weight.

Table XIV shows the phenotypic correlation and regression values obtained between production traits and certain carcass quality factors.

It becomes evident upon examination of the results of Table XIV that the trends concerning quality factors are less clearly defined. Birth weight was negatively correlated with carcass grade in both time periods with the higher negative value appearing in period 2. This trend agrees with work done by Yao et al. (1953), Woodward et al. (1962) and Shelby et al. (1963).

In period 1, weaning weight, 180-day adjusted weaning weight and daily gain from birth to weaning all showed low but positive relationships with carcass grade. This is in agreement with Woodward et al. (1954), Woodward et al. (1959), Shelby et al. (1963), Swiger et al. (1965) and Dubose et al. (1967). These same variables were negatively related with grade in period 2.

TABLE XIV. SIMPLE CORRELATION AND REGRESSION COEFFICIENTS BETWEEN PRODUCTION TRAITS AND VARIOUS MEASURES OF CARCASS QUALITY OF 339 CROSSLINE HEREFORD STEERS.

		Slaughter Trait (y)							
Production Trait	(X)	Carcass grade	Dressing percent	Rib-eye area	1 Fat thickness	Average fat thickness	Rib-eye area/100 lbs. carc. wt.	Fat thickness/100 lbs. carc. wt.	Length rib-eye
Birth weight 1/	r	-.13	.12	.22**	-.05	-.01	-.15	-.17*	.27**
	b	-.02	.02	.03	-.001	-.005	-.004	-.0005	.26
2/	r	-.20**	-.13	-.07	-.15*	-.21**	-.16*	-.17*	.09
	b	-.03	-.02	-.01	-.002	-.09	-.003	-.0004	.07
Weaning weight	r	.08	.32**	.30**	.25**	.26**	-.39**	.04	.25**
	b	.001	.01	.01	.0006	.02	-.001	.00	.04
	r	-.24**	-.02	.05	.03	-.004	-.15*	-.004	.01
	b	-.004	-.0004	.001	.0001	-.0002	-.0004	-.00	.0005
Weaning age	r	.15	.14	.13	.12	.07	-.19*	.02	.16*
	b	.01	.01	.01	.001	.02	-.003	.00	.08
	r	-.17*	.03	.01	.06	.03	-.07	.06	-.01
	b	-.01	.003	.001	.0005	.001	-.001	.0001	-.003
180-day weight	r	.02	.29**	.26**	.22**	.27**	-.35**	.04	.21**
	b	.0004	.01	.01	.001	.02	-.002	.00	.04
	r	-.20**	-.06	.05	.02	-.02	-.16*	-.03	-.01
	b	-.004	-.002	.001	.00	-.001	-.0005	-.00	-.001

1/ = Period 1
2/ = Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
* = $P < .05$
** = $P < .01$

TABLE XIV. (Continued)

Production Trait	(X)	Slaughter Trait (y)							
		Carcass grade	Dressing percent	Rib-eye area	1 Fat thickness	Avg. fat thickness	Rib-eye area/100 lbs. carc. wt.	Fat thickness/100 lbs. carc. wt.	Length rib-eye
Final weight 1/	r	-.01	.14	.39**	.19*	.25**	-.44**	-.05	.39**
	b	-.0001	.003	.01	.0004	.01	-.001	-.00	.04
2/	r	.20**	-.26**	.26**	-.01	.01	-.21**	-.13	.14
	b	.005	-.01	-.01	-.00	.001	-.001	-.0001	.02
Avg. daily gain	r	-.17*	-.17*	.25**	-.01	.07	-.24**	-.15	.32**
	b	-.82	-1.05	1.23	-.01	1.14	-.24	-.02	12.76
	r	.18*	-.44**	.12	-.12	-.09	-.11	-.17*	.09
	b	.91	-3.01	.50	-.07	-1.65	-.07	-.02	2.70
Gain/day @ wean	r	.05	.29**	.23**	.25**	.29**	-.34**	.08	.17*
	b	.20	1.61	1.02	.16	4.51	-.30	.01	5.96
	r	-.17*	-.02	.08	.03	.02	-.12	-.01	-.02
	b	-.71	-.14	.27	.01	.28	-.07	-.001	-.38
Gain/day @ slaughter	r	-.08	.06	.33**	.16*	.23**	-.37**	-.04	.34**
	b	-.53	.52	2.21	.15	5.43	-.50	-.01	18.36
	r	.05	-.35**	.16*	-.07	-.09	-.16*	-.15	.02
	b	.40	-3.58	1.00	-.06	-2.35	-.16	-.02	2.18

1/ = Period 1
2/ = Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
* = $P < .05$
** = $P < .01$

TABLE XIV. (Continued)

		Slaughter Trait (y)							
Production Trait	(X)	Width rib-eye	Rib-eye index	Cutability	Marbling score	Shear force	Percent lean	Percent fat	Percent bone
Birth weight 1/	r	.07	.13	.004	-.16	-.17	.16	.24	-.08
	b	.32	.31	.001	-.02	-.07	.19	.16	-.03
2/	r	-.19*	.22**	.06	-.16*	.08	.06	-.21*	.19*
	b	-.89	.45	.01	-.01	.01	.03	-.11	.05
Weaning weight	r	.13	.09	-.27**	.10	-.21	-.07	.49	-.44
	b	.09	.03	-.01	.002	-.01	-.01	.03	-.01
	r	-.01	.01	-.02	-.05	.14	-.03	-.18*	.14
	b	-.01	.003	-.0003	-.001	.003	-.002	-.01	.01
Weaning age	r	.07	.08	-.12	.13	-.03	-.16	.38	-.18
	b	.18	.10	-.01	.01	-.01	-.07	.09	-.02
	r	-.02	-.0002	-.05	-.06	-.002	-.01	-.10	.01
	b	-.04	-.0002	-.004	-.003	-.0003	-.004	-.03	.002
180-day weight	r	.11	.07	-.25**	.05	-.31	.02	.49	-.60*
	b	.10	.03	-.01	.001	-.02	.005	.06	-.03
	r	-.02	.02	-.001	-.02	.16	-.03	-.16	.17
	b	-.01	.01	-.00	-.0004	.005	-.003	-.02	.01

1/ = Period 1
2/ = Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
* = $P < .05$
** = $P < .01$

TABLE XIV. (Continued)

Production Trait	(X)	Width rib-eye	Rib-eye index	Cutability	Marbling score	Shear force	Percent lean	Percent fat	Percent bone
		Slaughter Trait (y)							
Final weight 1/	r	.18*	.12	-.22**	.01	-.09	.05	.33	-.19
	b	.11	.04	-.004	.0002	-.004	.01	.02	-.01
2/	r	.16*	-.05	.01	.22**	-.02	-.02	.08	-.07
	b	.14	-.02	.0003	.004	-.0005	-.002	.01	-.004
Avg. daily gain	r	.13	.09	-.04	-.09	.19	.25	-.19	.28
	b	27.88	8.89	-.22	-.46	2.72	8.90	-3.96	2.91
	r	.03	.02	.09	.13	.03	.06	.0004	-.01
	b	6.43	1.59	.42	.45	.19	1.57	.01	-.14
Gain/day @ wean	r	.11	.04	-.27**	.08	-.30	.002	.45	-.60*
	b	18.93	3.85	-1.43	.42	-4.23	.08	9.86	-6.24
	r	.03	-.03	.002	.004	.16	-.04	-.13	.14
	b	5.28	-2.07	.01	.01	.88	-.71	-2.38	1.35
Gain/day @ slaughter	r	.15	.09	-.13	-.02	-.08	.15	.14	-.12
	b	41.32	12.74	-1.09	-.14	-2.08	9.47	5.53	-2.15
	r	.08	-.05	.01	.10	.16	.06	-.07	.12
	b	22.61	-5.49	.57	.54	1.63	2.04	-2.22	2.24

1/ = Period 1
2/ = Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
* = $P < .05$
** = $P < .01$

At the same time the fattening period growth traits (average daily gain on feed, final weight and daily gain from birth to slaughter) all showed negative relationships with carcass grade during period 1 and positive relationships during period 2. Undoubtedly, compensatory gain is the primary cause of the differences in the signs of the coefficients within each time period between carcass grade and weanling traits and between carcass grade and feedlot traits. Higher weaning weights generally are associated with lower feedlot daily gains. However, the reasons for weanling traits being positively correlated with carcass grade in period 1 but negatively correlated in period 2 and for feedlot traits to be negatively correlated with carcass grade in period 1 but positively correlated in period 2 are not evident. Since the preweaning management of the herd was the same during both periods it can be concluded that preweaning growth had a more favorable influence on carcass grade under time-constant feeding conditions than under weight-constant conditions. It can also be concluded that the present study indicates the feedlot period is a more favorable influence than the preweaning period when cattle are slaughtered on a weight or grade-constant basis.

All the growth traits with the exception of birth weight and average daily gain are correlated significantly ($P < .05$) with fat thickness measured at the 12th rib during period 1 but the correlations drop to near zero during period 2. The low values in period 2 are due to the effect of holding final weight relatively constant during the period. The same general trend appears in the correlations involving percent separable fat in the 12th rib section. With the exception of average daily gain, all the growth traits show positive correlations with percent fat during period 1 and near zero or slightly negative values during period 2. Average daily gain showed low and, in general, slightly negative correlations with these measures of fatness (fat thickness at the 12th rib and percent separable fat). Thus it can be concluded that if the larger animals tended to be fatter, but average daily gain on feed had little or no effect on fatness, then apparently preweaning growth established their extra degree of fatness. In other words, preweaning growth had a stronger influence on carcass fatness or finish than did postweaning growth. This is not in agreement with work done by Woodward et al. (1954), Woodward et al. (1959), Shelby et al. (1963), Swiger et al. (1965) and Dubose et al. (1967). The correlation of -.12 between daily gain and fat thickness in period 2 of the present study is in general agreement with the partial correlation, holding final weight constant, of -.21 reported by Woodward et al. (1954).

Growth traits had a highly significant ($P < .01$) positive effect on area of rib-eye in period 1 but in period 2, the correlations, with the exception of those involving final weight and gain per day-of-age at slaughter, dropped to non-significant levels. These relationships agree with the results of Woodward et al. (1954). They studied animals slaughtered after a time-constant feed period and then calculated partial correlations between production traits and area of rib-eye, holding final weight constant, and found the correlations to drop to low, nonsignificant levels. Other workers have also reported strong positive correlations between growth traits and area of rib-eye, (Cartwright et al., 1958; Woodward et al., 1959; Brown et al., 1962; Shelby et al., 1963; Christian et al., 1965; Dubose et al., 1967; and Abraham et al., 1968).

All the production traits studied showed negative correlations with rib-eye area per 100 pounds of carcass weight. These findings agree with those of Cartwright et al. (1958) and Neville et al. (1963). The fact that growth traits were positively correlated with total rib-eye area but negatively correlated with rib-eye area per 100 pounds of carcass indicates that rib-eye area does not increase proportionally with increased total body growth.

Growth traits exerted a highly significant ($P < .01$) effect on length of rib-eye during period 1. Width was also positively affected during this period but not enough for the relationship to be significant at the 5 percent level. Consequently, rib-eye index was unaffected by growth patterns. Growth did not appear to appreciably affect the rib-eye length, width or index in period 2.

Production traits showed little or no correlation with cutability during period 2. However, during period 1, a considerable negative relationship was found to exist. Those correlations between cutability and weaning weight, 180-day weaning weight, final weight and gain from birth to weaning all proved to be highly significant ($P < .01$) in period 1. These negative values agree with those reported by Birkett et al. (1965) and Swiger et al. (1965).

The correlations between production traits and marbling score indicate a low relationship. Birth weight was negatively correlated with marbling score in both time periods. Where weaning weight, weaning age, 180-day weaning weight and gain from birth to weaning were concerned, the stronger positive correlations, although low, appeared in period 1. However, with final weight, average daily gain and gain from birth to slaughter, the stronger positive correlations appeared in period 2. It would appear from these data that, although the correlations are small, weanling traits had a stronger influence on marbling than did feedlot characteristics when cattle were slaughtered after a time-constant feeding period. However, when slaughtered at the same weight, the feedlot traits showed a more favorable influence.

At this point it should be remembered that the recording of data on shear force, percent separable lean, fat and bone was begun in 1959 and that period 1 contains only data from 1959 for these traits. Consequently, the numbers involved are quite small and the correlations are subject to considerable sampling error.

The correlations during period 1 indicate a negative relationship between growth rate and shear force. Average daily gain was the only growth measure which was correlated positively during this time period. During period 2, the correlations tended to be low but positive in most cases. These results agree with those of Woodward _et al._ (1959), Brown _et al._ (1962), Matthews and Bennett (1962) and Suess _et al._ (1966).

In period 1 (1959 only) growth traits seemed to exert a small positive effect on percent separable lean and fat from the 12th rib section and a reasonably strong negative effect on percent bone. During period 2 the growth traits, in general, showed little effect on percent lean, a slightly negative effect on percent fat, and a slight positive effect on percent bone. These results from period 1 tend to agree with previous studies

(Cartwright et al., 1958; Woodward et al., 1959; Brown et al., 1962; Brackelsburg and Willham, 1968) which reported a general positive relationship between growth traits and percent fat and negative relationships with percent lean and bone.

Sire-offspring Study

Table XV presents the correlations and regression coefficients obtained between 10 sire traits and various weight, age and linear carcass measurements of their steer progeny. It can be noted, as was the case with the phenotypic correlation study, that slaughtering cattle on a weight-constant basis generally tends to reduce the magnitudes of the correlations although the trend was less pronounced and defined in this part of the analysis.

Adjusted 180-day weaning weight, final weight, daily gain on feed test, score at end of feed test and gain per day-of-age at weaning were all positively correlated at the 5 percent level with progeny slaughter weight during period 1. Inbreeding of the sire did not appear to influence the slaughter weight or carcass weight of steer progeny in period 1.

Sire growth rate appeared to exert a very slight negative effect on progeny slaughter age when animals were killed at the same approximate weight.

In general, sire feedlot characteristics such as final weight, daily gain and score at end of feed test were more influential than weanling traits in their effect on linear carcass measurements of steer progeny. This is, however, with the exception of 180-day adjusted weaning weight which was correlated at the 5 percent level with width of shoulder and length of loin and at the 1 percent level with length of body.

TABLE XV. SIMPLE CORRELATION AND REGRESSION COEFFICIENTS BETWEEN TEN SIRE TRAITS AND VARIOUS WEIGHT, AGE AND LINEAR CARCASS MEASUREMENTS OF CROSSLINE HEREFORD STEER PROGENY.

		Progeny Slaughter Trait (y)										
Sire Trait	(X)	Slaughter weight	Slaughter age	Carcass weight	Width round	Width shoulder	Depth body	Circumfer-ence round	Length body	Length leg	Length loin	Plumpness index
Inbreeding of 1/	r	.004	-.07	-.01	.24	-.03	-.15	-.19	.02	.09	.13	-.25
sire	b	.02	-.08	-.04	.55	-.04	-.17	-.53	.07	.23	.22	-.07
2/	r	.26	.04	.26	.13	.35*	.07	-.03	.08	-.07	-.07	.08
	b	1.37	.11	.87	.23	1.39	1.10	-.77	1.18	-1.33	-1.38	.45
Birth weight	r	.17	.20	.13	-.06	.30	.13	.20	.18	.28	.07	.02
	b	.90	.20	.47	-.12	.35	.13	.49	.48	.60	.11	.005
	r	.21	-.20	.26	.39*	-.14	-.09	.20	-.15	.22	.17	-.21
	b	.64	-.30	.48	.41	-.33	-.89	2.73	-1.24	2.37	1.88	-.66
Weaning weight	r	.27	.13	.23	.31	.36*	-.21	.001	.32	.18	.18	-.30
	b	.20	.02	.12	.08	.06	-.03	.0003	.12	.05	.04	-.01
	r	.01	.03	-.05	.16	.03	.17	-.13	.15	-.19	-.18	.17
	b	.004	.01	-.02	.03	.01	.26	-.29	.19	-.33	-.32	.09
Weaning age	r	-.03	.06	-.06	.14	.19	-.37*	-.10	-.03	-.09	-.16	-.17
	b	-.09	.03	-.10	.13	.11	-.19	-.12	-.05	-.09	-.12	-.02
	r	-.03	.13	-.10	-.12	-.02	.01	-.07	.03	-.08	-.05	.06
	b	-.06	.15	-.14	-.09	-.04	.06	-.76	.22	-.68	-.41	.16
180-day weight	r	.38*	.12	.34	.30	.35*	-.03	.09	.45**	.27	.37*	-.22
	b	.37	.02	.22	.11	.07	-.01	.04	.22	.10	.10	-.01
	r	.16	-.06	.11	.20	.25	.18	-.12	.15	-.16	-.19	.16
	b	.09	-.02	.04	.04	.11	.32	-.31	.23	-.32	-.38	.09
Weaning score	r	.26	.23	.26	.33	.43*	-.22	.14	.19	.18	.25	-.03
	b	2.32	.39	1.54	1.10	.87	-.37	.57	.88	.65	.62	-.01
	r	.06	-.005	-.03	.01	.17	.25	-.28	.21	-.33*	-.32	.32
	b	.31	-.01	-.09	.02	.62	3.78	-6.06	2.66	-5.70	-5.61	1.63
Final weight 1/	r	.43*	.20	.35*	.39*	.51**	-.08	.15	.51**	.32	.25	-.24
	b	.25	.02	.14	.08	.07	-.01	.04	.16	.08	.04	-.01
2/	r	.21	-.08	.16	.23	-.02	.02	.06	-.06	.06	.03	-.06
	b	.09	-.02	.05	.04	-.01	.03	.12	-.07	.10	.05	-.03

1/ Period 1
2/ Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
* = P<.05
** = P<.01

TABLE XV. (Continued)

Sire Trait	(X)	Slaughter weight	Slaughter age	Carcass weight	Width round	Width shoulder	Depth body	Circumfer-ence round	Length body	Length leg	Length loin	Plumpness index
		Progeny Slaughter Trait (y)										
Avg. daily gain	r	.43*	.27	.39*	.37	.40*	.31	.31	.48**	.50**	.25	-.01
	b	82.90	10.20	50.89	26.56	17.39	11.27	27.40	47.23	39.31	13.72	-.09
	r	.14	-.09	.09	.10	-.44*	-.11	.24	-.25	.31	.28	-.30
	b	18.63	-6.12	7.50	4.41	-44.06	-44.06	141.35	-87.02	144.01	132.88	-40.89
Score end of feed test	r	.35*	.18	.29	.37*	.49**	-.28	.24	.34	.24	.28	-.01
	b	3.30	.31	1.77	1.27	1.01	-.48	1.02	1.63	.91	.71	-.01
	r	.11	-.04	.01	.15	.07	.26	-.10	.13	-.12	-.16	.16
	b	.90	-.17	.06	.40	.43	6.50	-3.64	2.71	-3.34	-4.49	1.28
Gain/day @ wean	r	.37*	.09	.34	.32	.30	-.05	.05	.44*	.23	.37*	-.23
	b	65.85	3.24	39.93	21.13	12.09	-1.73	4.42	39.86	16.31	18.26	-1.81
	r	.13	-.02	.08	.13	.29	.20	-.16	.19	-.21	-.22	.20
	b	13.70	-1.31	5.07	4.92	23.29	68.89	-77.89	52.84	-77.66	-85.61	22.45

r = Correlation coefficient
b = Regression coefficient of y on x
* = $P < .05$
** = $P < .01$

All the measures of sire growth, with the exception of daily gain on feed, are correlated positively with carcass width and length measurements and negatively with depth of body in period 1. In most cases, however, the negative correlations with depth of body were very low. The largest of these correlations occurred with weaning score and score at end of feed test.

Table XVI presents the correlation and regression coefficients obtained between the 10 sire traits and various carcass quality factors of their steer progeny.

There appears to be little if any relationship between sire growth rate, scores or inbreeding and offspring carcass grade. None of the correlations are statistically significant at the 5 percent level and are of little predictive value. The correlations of weights and gains with carcass grade show a slightly stronger positive relationship to exist in period 2 than in period 1.

Sire growth traits and scores, with the exception of birth weight, positively influenced progeny rib-eye area during period 1. Score at end of feed test and gain per day-of-age at weaning were significantly (P .05) correlated with area of rib-eye. At the same time, these same growth traits and scores were associated with a decrease in fatness measured at the 12th rib. The desirability of these relationships is exemplified by the positive correlations between growth traits and scores and cutability. Faster growing and higher scoring bulls tended to produce offspring of higher cutability and, consequently, desirability according to today's market standards.

TABLE XVI. SIMPLE CORRELATION AND REGRESSION COEFFICIENTS BETWEEN TEN SIRE TRAITS AND VARIOUS MEASURES OF CARCASS QUALITY OF CROSSLINE HEREFORD STEER PROGENY.

		Progeny Slaughter Trait (y)							
Sire Trait	(X)	Carcass grade	Dressing percent	Rib-eye area	1 Fat thickness	Avg. fat thickness	Rib-eye area/100# carcass	Fat thickness/100# carcass	Length rib-eye
Inbreeding of 1/	r	.06	.06	-.04	-.02	.02	-.07	-.06	-.03
sire	b	.005	.006	-.003	-.0002	.004	-.001	-.0001	-.01
2/	r	-.16	.03	.03	.21	.10	-.14	.19	.13
	b	-.03	.005	.004	.004	.05	-.003	.001	.11
Birth weight	r	.18	-.15	-.05	-.18	.10	-.21	-.21	.18
	b	.01	-.01	-.004	-.001	.02	-.002	-.0003	.08
	r	-.05	.11	.26	-.01	.09	.13	-.07	.37*
	b	-.005	.01	.02	-.0001	.03	.002	-.0001	.18
Weaning weight	r	.01	-.02	.27	-.02	-.07	.08	-.12	.25
	b	.0001	-.0003	.003	-.00	-.002	.0001	-.00	.02
	r	.08	-.11	.09	.08	.001	.03	.10	.02
	b	.0013	-.002	.001	.0001	.00	.0001	.00	.002
Weaning age	r	.03	-.12	.01	.10	.07	.15	.10	.07
	b	.001	-.01	.0002	.0003	.01	.001	.0001	.02
	r	-.15	-.13	.07	-.001	.002	.06	.04	.03
	b	-.01	-.01	.004	-.00	.0004	.0005	.00	.01
180-day weight	r	-.04	.05	.34	-.10	-.16	-.02	-.23	.32
	b	-.001	.001	.004	-.0001	-.005	-.00	-.0001	.03
	r	.16	-.09	.08	.03	-.01	-.04	.03	-.04
	b	.003	-.001	.001	.0001	-.0003	-.0001	.00	-.003

1/ = Period 1
2/ = Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
* = P ≤ .05

TABLE XVI. (Continued)

Sire Trait	(X)	Carcass grade	Dressing percent	Rib-eye area	1 Fat thick-ness	Avg. fat thickness	Rib eye area/100# carcass	Fat thick-ness/100# carcass	Length rib-eye
		Progeny Slaughter Trait (y)							
Weaning score 1/	r	.20	.14	.25	-.03	.05	-.12	-.17	.17
	b	.02	.02	.03	-.0004	.01	-.002	-.0004	.13
2/	r	-.02	-.15	-.14	.31	.12	-.25	.32	.03
	b	-.003	-.02	-.02	.005	.06	-.005	.001	.02
Final weight	r	-.09	-.14	.31	-.15	-.08	-.001	-.28	.32
	b	-.001	-.001	.002	-.0001	-.001	-.00	-.00	.02
	r	.06	-.09	.14	.03	.10	-.03	.01	.02
	b	.001	-.001	.002	.00	.005	-.00	.00	.002
Avg. daily gain	r	-.05	-.04	.25	-.42*	-.11	-.16	-.54**	.07
	b	-.12	-.13	.63	-.11	-.61	-.06	-.03	.20
	r	-.09	-.12	.06	-.02	.05	-.03	-.04	-.05
	b	-.40	-.47	.22	-.01	.64	-.02	-.003	-.004
Score end of feed test	r	-.04	-.09	.38*	-.12	-.25	.06	-.29	.28
	b	-.005	-.01	.05	-.001	-.07	.001	-.001	.22
	r	-.04	-.21	-.08	.03	.05	-.14	.04	-.0003
	b	-.01	-.05	-.02	.001	.04	-.004	.0002	-.0004
Gain/day @ wean	r	-.07	.08	.36*	-.07	-.19	.02	-.20	.30
	b	-.18	.24	.85	-.02	-1.00	.01	-.01	4.46
	r	.18	-.11	.03	.03	-.03	-.07	.04	-.11
	b	.61	-.34	.08	.01	-.29	-.03	.003	-1.93

1/ = Period 1
2/ = Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
* = $P < .05$
** = $P < .01$

TABLE XVI. (Continued)

Sire Trait		(X)	Width rib-eye	Rib-eye index	Cutability	Shear force	Percent lean	Percent fat	Percent bone	Marbling score
			Progeny Slaughter Trait (y)							
Inbreeding	1/	r	-.02	.06	-.001	-.19	-.34	.41	-.43	-.04
		b	-.06	.08	-.0001	-.05	-.15	.24	-.07	-.003
	2/	r	.02	.07	.05	.03	.10	.02	.01	-.06
		b	.14	.18	.08	.03	.06	.04	.01	-.01
Birth weight		r	-.20	.25	-.01	-.06	-.61	.79	-.99**	-.14
		b	-.53	.32	-.0005	-.03	-.39	.68	-.25	-.01
		r	.05	.14	-.18	-.17	-.12	-.17	-.22	-.19
		b	.17	.22	-.16	-.10	-.04	-.15	-.20	-.01
Weaning weight		r	.17	.03	.12	.69	.19	.02	-.48	-.24
		b	.07	.01	.001	.02	.01	.001	-.01	-.002
		r	.10	-.07	.15	.08	.02	.20	.03	.13
		b	.06	-.02	.02	.01	.001	.03	.005	.002
Weaning age		r	-.08	.16	-.04	.65	.42	-.21	-.43	-.30
		b	-.11	.10	-.001	.06	.07	-.04	-.03	-.01
		r	-.04	.06	.06	-.05	-.13	.06	-.05	-.13
		b	-.11	.08	.04	-.02	-.04	.04	-.04	-.01
180-day weight		r	.25	-.02	.18	.60	-.001	.18	-.48	-.17
		b	.12	-.004	.002	.03	-.0001	.02	-.01	-.002
		r	.18	-.17	.15	.11	.11	.19	.06	.23
		b	.13	-.05	.03	.01	.01	.03	.01	.003

1/ = Period 1
2/ = Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
** = $P < .01$

TABLE XVI. (Continued)

Sire Trait	(X)	Width rib-eye	Rib-eye index	Cutability	Shear force	Percent lean	Percent fat	Percent bone	Marbling score
		Progeny Slaughter Trait (y)							
Weaning score	r	.16	.01	.13	.36	-.35	.50	-.59	-.07
	b	.75	.01	.01	.13	-.20	.38	-.13	-.01
	r	-.14	.13	.28	.22	.16	.30	.23	.19
	b	-.83	.35	.41	.21	.09	.45	.35	.02
Final weight	r	.22	-.01	.18	.80	.41	-.21	-.33	-.33
	b	.07	-.002	.001	.02	.01	-.01	-.005	-.002
	r	.07	-.04	-.05	-.16	-.16	-.06	-.15	-.04
	b	.04	-.01	-.01	-.01	-.01	-.01	-.02	-.0004
Avg. daily gain	r	.33	-.30	.28	-.28	.30	-.51	.91*	.02
	b	33.05	-14.21	.58	-7.47	12.74	-28.97	14.86	.05
	r	-.03	-.01	-.27	-.31	-.21	-.33	-.25	-.24
	b	-4.97	-.91	-10.92	-7.98	-3.01	-12.49	-9.87	-.76
Score end of feed test	r	.28	-.07	.29	.75	.59	-.54	.34	-.40
	b	1.34	-.15	.03	.34	.43	-.52	.09	-.04
	r	-.02	.01	.13	.06	.12	.07	.14	.05
	b	-.23	.06	.30	.09	.10	.15	.31	.01
Gain/day @ wean	r	.30	-.07	.19	.64	.08	.09	-.38	-.15
	b	27.63	-3.18	.36	5.36	1.03	1.64	-1.95	-.25
	r	.18	-.21	.19	.14	.14	.22	.10	.28
	b	23.56	-11.88	6.03	2.88	1.68	6.87	3.15	.71

1/ = Period 1
2/ = Period 2
r = Correlation coefficient
b = Regression coefficient of y on x
* = P < .05

Sire growth traits and scores were negatively associated with marbling scores during period 1 and, generally, slightly positively associated in period 2. Again it should be noted that the recording of marbling score was begun in 1956 and period 1 for this trait contains relatively few observations.

It must be remembered, also, that the recording of shear force and 12th rib separation data was begun in 1959 and that period 1 contains very small numbers where these measurements are concerned. In this portion of the analysis there are only five observations in period 1 since five sires were used in 1959.

In period 1, all the sire growth traits and scores except birth weight and daily gain on feed test were positively correlated with shear force. None of the relationships were significant at the 5 percent level of probability, however. In period 2, all the relationships observed were quite low. Sire weaning weights, score and gain to weaning were slightly positively correlated with shear force, while feed test characteristics and birth weight were slightly negatively correlated.

As with shear force, the correlations concerning percent lean, fat and bone separations of the 12th rib section are not to be considered reliable values. This again is due to the small numbers in period 1 and the confounding of the results by slaughtering at a constant weight in period 2. A large number of animals slaughtered after a time-constant feeding period would have been most desirable in examining these relationships.

During period 1, final weight showed the most favorable influence on 12th rib separation being positively correlated with percent lean and negatively correlated with percent fat and percent bone. Daily gain also showed a positive relationship with percent lean and a negative relationship with percent fat. The extremely high correlation between daily gain and percent bone as well as between birth weight and percent bone must, in part, be attributed to random variation within the small sample.

The correlations in period 2, as expected, were generally low in magnitude. Sires' gain from birth to weaning and daily gain on feed appeared to show the strongest general effect with gain from birth to weaning having a positive influence on all three rib section components and daily gain on feed showing negative effects on all three components.

Heritability Estimates

Heritability estimates were calculated for several of the growth traits studied by the method of multiplying the regression of offspring on sire by two. These estimates are presented in Table XVII.

TABLE XVII. HERITABILITY ESTIMATES OF VARIOUS PRODUCTION TRAITS AS ESTIMATED FROM REGRESSION OF OFFSPRING ON SIRE.

Trait Studied	By X	Heritability Estimate
Birth weight	.2519	50%
Actual weaning weight	-.0303	-6%
180-day adjusted weight	.0045	1%
Final weight 1/	.2674	53%
Average daily gain 1/	.1714	34%
Daily gain birth to weaning	-.0190	-4%

1/ Utilizing data from period 1 (time-constant) only.

In obtaining these estimates the overall regressions involving all 15 years were calculated for birth weight, weaning weight, 180-day adjusted weaning weight and gain from birth to weaning since pre-weaning management of the bulls and steers was generally the same during both time periods. However, since the bulls were fed entirely on a time-constant basis, regression values for period 1 only were used to estimate heritabilities for feedlot characteristics.

The estimate of 0.50 for birth weight agrees generally with reports of previous workers. It is a little higher than the average reported. It is considerably higher than the 0.35 obtained by Koch and Clark (1955b) utilizing the offspring on sire regression.

The estimates of -.06 for actual weaning weight and 0.01 for 180-day adjusted weaning weight are not in agreement with the results of any of the previous workers reviewed. The reason for this is not apparent since the bulls and steers were handled essentially the same during the preweaning period.

The estimate of 0.53 for final weight obtained in the present study is somewhat below the average but within the range of those in the studies reviewed. It should be pointed out that the studies reviewed involved estimates obtained only by the paternal half-sib method which generally tends to produce somewhat higher estimates than does the offspring on sire regression method. This is due to the fact that the sampling errors of the paternal half-sib method are high. The sire component of variance is multiplied by a factor of 4 so that any errors in the estimate of the sire component are similarly inflated. Any environmental effects that are peculiar to a particular sire progeny are included in the sire component and multiplied by 4. This explanation, plus further details of the comparison of the two methods, was given by Kincaid and Carter (1958).

The above situation also applies to the estimate for average daily gain. The estimate of 0.34 obtained in the present study agrees well with the 0.38 obtained by Kincaid and Carter (1958) by the sire-offspring regression method but is somewhat below the average of the estimates obtained by the half-sib method.

The estimate of -.04 for gain from birth to weaning agrees generally with Gregory *et al.* (1950), Swiger *et al.* (1962) and Pahnish *et al.* (1964) but is in large disagreement with the values reported by the majority of studies reviewed.

SUMMARY

Cattle records covering a 15-year period (1952-1966) from the North Montana Branch Experiment Station were analyzed to study the effects of growth traits on carcass characteristics. The data were analyzed by simple correlation and regression analyses. The study consists of two general parts: (1) a phenotypic correlation study in which eight production traits of 339 crossline Hereford steers were correlated with 27 of their own slaughter and carcass traits, and (2) a sire-offspring study utilizing data from 78 sires and their progeny groups. Ten production characteristics of the sires were related to 27 slaughter or carcass traits of their steer progeny.

Each study was broken into two parts: period 1 which included data from 1952-1959, and period 2 which covers 1960-1966. This was due to the fact that during period 1, the cattle were slaughtered under time-constant feeding conditions while during period 2, they were slaughtered on a relatively weight-constant basis. The data was first analyzed by years. The intra-year sums of squares and sums of crossproducts were than pooled for the two time periods. The correlation and regression values obtained in this manner for the two time periods were corrected for year effects within period.

Heritability estimates were obtained for birth weight, weaning weight, 180-day adjusted weaning weight, final weight, average daily gain on feed and daily gain from birth to weaning. These estimates were obtained by doubling the offspring-on-sire regression for each trait.

Phenotypic Correlations Study

Phenotypic correlations (steer data): All the values reported in

period 1 between growth traits and measures of carcass size were significant at least at the 5 percent level. The coefficients from period 2 were positive but of lower magnitude than those in period 1. This is due to the effect of holding final weight relatively constant during this period and this same general effect was evident throughout the analyses.

When final weight was constant there was a highly significant ($P<.01$) negative relationship between all growth traits and slaughter age.

Birth weight was negatively correlated with carcass grade in both time periods. In period 1 weanling traits were positively related with grade while feedlot traits were negatively correlated. However, during period 2, weanling traits were negatively correlated with grade while feedlot traits were positively related.

All growth traits were positively correlated with carcass fatness as measured at the 12th rib and in the percent separable fat of the 12th rib section. Preweaning growth had a stronger effect on carcass fatness than did postweaning growth. A negative correlation was found between daily gain on feed and fat thickness during period 2.

Growth traits had a highly significant ($P<.01$) positive relationship with rib-eye area in period 1. All the traits were negatively correlated, however, with rib-eye area per 100 pounds of carcass weight.

During period 1, a relatively strong negative relationship was found between growth traits and cutability. The negative correlations between cutability and weaning weight, 180-day adjusted weaning weight, final weight, and gain from birth to weaning were all significant at the 1 percent level.

A low relationship was found to exist between growth traits and marbling score. Although all the correlations were small, it appeared that weanling traits had a stronger influence on marbling than did feedlot traits during period 1. However, the opposite appeared to be true during period 2.

Correlations concerning shear force and 12th rib separation data during period 1 are not to be considered highly reliable since recording of the data was begun in 1959 and, consequently, period 1 contains relatively few observations.

A negative relationship was found between growth traits and shear force in period 1, with the exception of average daily gain on feed. During period 2, the correlations were low but positive. During period 1, growth traits showed a small positive relationship with percent separable lean and fat of the 12th rib section, and a reasonably strong negative relationship with percent bone. During period 2, they had little effect on percent lean, a negative effect on percent fat and a positive effect on percent bone.

Sire-offspring Study

Sire 180-day adjusted weaning weight, final weight, daily gain on feed test, score at end of feed test, and gain per day-of-age at weaning were all significantly ($P < .05$) positively correlated with progeny slaughter weight during period 1. Inbreeding of sire did not influence slaughter or carcass weight.

Sire feedlot characteristics were generally more influential than weanling traits in relationship with their effect on progeny line or carcass measurements. However, 180-day adjusted weaning weight was significantly ($P < .05$) correlated with width of shoulder and length of loin and highly significantly ($P < .01$) correlated with length of body.

Little relationship was found to exist between sire growth rate, scores or inbreeding and offspring carcass grade. A positive relationship with area of rib-eye was found during period 1 with score at end of feed test and gain per day-of-age being significantly ($P < .05$) correlated. The sire growth traits were also associated with a decrease in fatness measured at the 12th rib. Faster growing and higher scoring bulls tended to produce offspring of higher cutability.

Sire growth traits and scores were negatively associated with marbling during period 1 and positively correlated in period 2. They showed a general positive relationship with shear force during period 1. In period 2, sire weanling traits were positively related to shear force while feedlot traits were negatively related.

During period 1, sire final weight showed the most favorable influence on 12th rib separation being positively correlated with percent lean and negatively correlated with percent fat and percent bone. Daily gain was also positively correlated with percent lean and negatively related to percent fat. During period 2 sire gain from birth to weaning and daily gain on feed showed the strongest effect on rib section components with gain from birth to weaning having a positive relationship with all three components and daily gain on feed having a negative relationship with all three components.

Heritability Estimates

Heritability estimates were calculated as follows: birth weight, 50%; weaning weight, -6%; 180-day adjusted weaning weight, 1%; final weight, 53%;

average daily gain, 34%; and daily gain from birth to weaning, -4%. The reason for the negative values for weanling traits is not apparent since the bulls and steers were handled essentially the same during the preweaning period.

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