

/FACTORS AFFECTING BULL PERFORMANCE
ON CENTRAL TESTS/

by

BARBARA JEAN WARD

B.S., Purdue University, 1986

A MASTER'S THESIS

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1989

Approved by:


Major Professor

LD
2668
.74
ASL
1981
W37
c.2



ALL208 617828

TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES.	iv
ACKNOWLEDGMENTS	vi
DEDICATION.	viii
INTRODUCTION.	1
REVIEW OF LITERATURE.	3
Introduction	3
Sources of Variation	4
Effects of Breed and Sire	4
Non-genetic Factors	6
Heritabilities and Correlations.	11
Traits of Interest	17
Duration of Test	18
Summary.	19
MATERIALS AND METHODS	23
RESULTS AND DISCUSSION.	30
Pre-Test Performance Traits.	30
Average Daily Gains.	34
Weight Per Day of Age.	36
Other Performance Traits	38
Factors Affecting Sales Price.	43
Rank Correlation Analyses of 112 and 140-d.	44
Average Daily Gains	

TABLE OF CONTENTS, Continued

	<u>Page</u>
SUMMARY	68
LITERATURE CITED.	73
ABSTRACT OF THESIS	

LIST OF TABLES

		<u>Page</u>
TABLE 1.	HERITABILITY ESTIMATES OF WEIGHT TRAITS .	21
TABLE 2.	A SUMMARY OF RATE OF GAIN HERITABILITY. . ESTIMATES	22
TABLE 3.	NUMBER OF OBSERVATIONS BY BREED AND . . . LOCATION	27
TABLE 4.	NUTRIENT COMPOSITION OF SAMPLE RATIONS. . (D. M. BASIS)	28
TABLE 5.	SIMPLE MEANS AND STANDARD DEVIATIONS OF . PRE-TEST PERFORMANCE TRAITS BY BREED	29
TABLE 6.	LEAST SQUARES MEANS AND STANDARD ERRORS . OF PRE-TEST PERFORMANCE TRAITS BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, BREED, AND AGE OF DAM	47
TABLE 7.	PARTIAL REGRESSION COEFFICIENTS OF. . . . PRE-TEST PERFORMANCE TRAITS ON STARTING AGE	50
TABLE 8.	LEAST SQUARES MEANS AND STANDARD ERRORS . OF PRE-TEST PERFORMANCE TRAITS BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED	51
TABLE 9.	LEAST SQUARES MEANS AND STANDARD ERRORS . OF AVERAGE DAILY GAINS DURING TEST PERIOD BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, AND BREED	53
TABLE 10.	PARTIAL REGRESSION COEFFICIENTS OF. . . . AVERAGE DAILY GAINS ON STARTING AGE, FRAME SCORE, AND FRAME SCORE ²	55
TABLE 11.	LEAST SQUARES MEANS AND STANDARD ERRORS . OF AVERAGE DAILY GAINS DURING TEST PERIOD BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED	56

LIST OF TABLES, Continued

	<u>Page</u>
TABLE 12. LEAST SQUARES MEANS AND STANDARD ERRORS . OF WEIGHT PER DAY OF AGE BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, AND BREED	58
TABLE 13. PARTIAL REGRESSION COEFFICIENTS OF. . . . WEIGHT PER DAY OF AGE ON FRAME SCORE AND FRAME SCORE ²	60
TABLE 14. LEAST SQUARES MEANS AND STANDARD. . . . ERRORS OF WEIGHT PER DAY OF AGE BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED	61
TABLE 15. LEAST SQUARES MEANS AND STANDARD. . . . ERRORS OF OTHER PERFORMANCE TRAITS BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, AND BREED	63
TABLE 16. PARTIAL REGRESSION COEFFICIENTS OF ADJUSTED YEARLING WEIGHT, RIBEYE AREA, BACKFAT THICKNESS, AND SCROTAL CIRCUMFERENCE ON STARTING AGE, 0-140D ADG, ADJUSTED YEARLING WEIGHT, AND FRAME SCORE	65
TABLE 17. LEAST SQUARES MEANS AND STANDARD. . . . ERRORS OF OTHER PERFORMANCE TRAITS BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED	66

ACKNOWLEDGMENTS

First of all I would like to thank my husband, Marc Lee, for his love and encouragement during the difficult times. For without his continual show of support and understanding, this thesis would never have been written.

To my parents, who for 24 years have driven me to challenge myself and whose emotional and financial support have made this possible, I offer my sincere thanks, love, and appreciation. I can never say how much I depend on their continued support of my achievements.

I also wish to thank my brother, Robert and his family, Stacy Hartman, M.S., Dionne and Carl Perkins, and Marc's relatives, specifically Deidra, Monty, Vev, and CB, for the encouragement and support they have offered throughout this project.

No achievement is successful without the considerable commitment from student and teacher. Special thanks go to my major professor, Dr. Robert R. Schalles, for his expertise and demand for excellence throughout this project. I would also like to thank my committee members, Dr. Guy Kiracofe and Dr. Ken Kemp for their guidance and suggestions during the course of this research. To Dr. Keith Zoellner and Dr. Calvin Drake, I also extend my appreciation for their time and support during my project. I wish to thank Dr. Jack Riley, Head of the Department of

Animal Science and Industry at Kansas State University for providing me with the financial support for this project and for maintaining an excellent graduate program in Animal Science.

Lastly, I wish to thank my fellow graduate students for the support and distractions they provided throughout my tenure of study. Specifically I wish to thank Benton Glaze, Mark Johnson, Twig Marston, Carla McConnell, and Ana Pabon. To Dr. Linda Martin, my sincere appreciation for your continual support throughout my Master's program.

DEDICATION

This thesis is dedicated to

Phyllis Ann Hostetter

and

Jacob Raymond Hostetter

For providing me with the financial and emotional
support necessary to be all I can and for
giving me the genetic and environmental
basis from which to begin and an
example by which to live.

"proud of who you are,
where you are from,
and what you stand for lest you forget"

INTRODUCTION

The United States beef cattle industry of the 1980's has been confronted by many problems of both production and economic nature that were unheard of 50 years ago. Higher production costs coupled with changes in consumer demand for beef products and changed economic conditions have forced cattlemen to make production efficiency their number one priority.

The importation of many varying genotypes of cattle from Europe beginning in the late 1960's has resulted in a wide array of biological types and sizes of beef cattle in this country. The increase in varying genotypes has increased the need for accurate identification of more efficient bull breeds.

Central bull tests provide uniform environmental conditions under which superior bulls can be more easily identified. Superior bulls which sire rapid-gaining, more efficient, high quality calves can increase profits for both the producer and feeder. Rapid-gaining cattle make more efficient use of the management, labor, capital, facilities, and equipment resulting in increased demand for the superior bulls.

Recent trends toward rapid-gaining cattle have resulted in selection for larger framed bulls with heavier weights at earlier ages. As a result many

cattlemen have expressed concern regarding leanness and birth weights. Therefore, this study was undertaken with the following objectives:

- I. To evaluate breed differences in performance traits of bulls on central tests, as well as to examine yearly trends.
- II. To determine relationships between growth traits and other performance traits including ribeye area, backfat thickness, scrotal circumference, frame score, and sales price.
- III. To establish whether the length of central bull tests can be reduced to 112 days without serious loss of accuracy when predicting subsequent bull performance.

REVIEW OF LITERATURE

Introduction

Performance testing of beef bulls at central test stations has become quite popular. These tests are designed to enable breeders to identify bulls that gain faster and more efficiently. Lack of uniformity in the age of bulls starting test, length of testing period, conditions under which bulls are tested, and the pre-test environment limit the usefulness of the tests. Most tests involve bulls weaned when 6 to 8-mo old and delivered to test stations about 3 wk before the start of the test.

Although the primary objective of central bull testing is to identify genetically superior bulls, another important part is the education of producers regarding improvement of cattle through the use of performance testing. Bulls that will sire rapid-gaining, more efficient, high quality calves can increase profits for both the producer and feeder. Rapid-gaining cattle make more efficient use of management, labor, capital, facilities, and equipment. Of even greater importance is the more efficient feed utilization by such cattle as demonstrated in many previous studies (Winters and McMahon, 1933; Guilbert and Gregory, 1944; Knapp, Jr. and Baker, 1944; Patterson

et al., 1955; Koch et al., 1963; Brown and Keaton, 1974; Wilton and McWhir, 1985; Brown et al., 1986). Brown et al. (1986) summarized 21 yr of performance testing at Arkansas which included consignment bulls tested at 4 locations. This study provided individual feed efficiency in addition to rate of gain. The results showed the yearly rate of change in mean average daily gain (ADG) to be .05 lb (.02 kg) which translates into an increase of 1.05 lb (.48 kg) over the 21 yr period. Results also showed average yearly changes in final weight to be 5.9 lb (2.7 kg); daily feed consumption, .15 lb (.066 kg); and in feed per pound of gain, -.054 lb (-.024 kg). Silcox (1980) analyzed 3 yr of individual feed consumption test data and concluded ADG to be the best predictor of feed efficiency, accounting for 68% of differences in feed utilization.

Sources of Variation

Effects of Breed and Sire. Performance testing of beef bulls in Kansas has been carried out at 3 test stations over the past 16 yr. In theory, these central tests permit comparison of many contemporary bulls from different herds and breeds, reared together under uniform conditions. However, in order to compare bulls and make selection of herd sires as effective as

possible, it is necessary to know the influence of both inherited factors and non-genetic sources of variation.

The effect of breed is the most influential inherited factor. Schalles and Marlowe (1967) reported that breed of bull had a significant effect on lifetime ADG, test ADG, and 365-d weight. Baker et al. (1982) found definite breed differences for on-test weight, off-test weight, hip height, scrotal circumference, ADG on test, backfat thickness, and muscling. They also found that breed differences tended to parallel differences in breed physiology and sexual maturity patterns, although all breeds tended to grow in height at the same rate during the test period or from weaning to yearling. Brown et al. (1986) found breed of bull to be a significant source of variation in height at the hips. Henningsson (1986) showed breed to be highly significant ($P < .001$) for all traits studied.

Most researchers have been unable to separate out sire effects, another seemingly influential inherited factor. However, Schalles and Marlowe (1967) found the influence of sire within breed confounded with herd effects to have a significant effect on lifetime ADG, test ADG, and 365-d weight of individually-fed bulls at Culpepper while not significantly affecting group-fed bulls at Front Royal.

Non-genetic Factors. Many non-genetic factors influence bull test performance. Such factors include: season, test station, age of dam, age at start of test, and pre-test factors such as ADG and rearing environment.

Koch and Clark (1955) studied the influence of season of birth by regressing various traits on age at weaning. Calves born later in the calving season were slightly heavier at birth and grew more rapidly than calves born early in the season. This resulted in higher pre-weaning ADG and heavier weaning and on-test weights. Marlowe et al. (1965) found that calves born during March and April had the fastest gains when other environmental factors were held constant. Calves born in August and September had the slowest gains. They also established that year effects on gains were highly significant with breeds responding differently to the year differences. Schalles and Marlowe (1967) found a significant year effect on 365-d weight of individually-fed bulls at Culpepper and test ADG of group-fed bulls at Front Royal. Baker et al. (1982) found that season of birth had no influence on scrotal circumference, hip height, or weights of purebred Hereford and Angus bulls. Simm et al. (1985) established that season effects accounted for up to 29% of the variation in

cumulative food intake of artificially-reared bulls. Henningsson (1986) found season of birth to have a significant effect on daily gain and live weight at test start, but no significant influence on relative growth rate. Year of birth had a significant influence on daily gain of Swedish Red and White bulls but had no influence on relative growth rate. Henningsson (1986) also found the interaction of season by year to have a significant influence on daily gain and relative growth rate.

Henningsson (1986) reported that test station had a significant influence on daily gain and final weight for all bulls and time periods. He also demonstrated that differences in the environment at the stations caused significant differences in daily gain and relative growth rate. No other reports were found on the effect of test location; however a few reports mentioned the effects of year by location interaction. Brown et al. (1985) found that location of test had no effect on hip height; however the year by location interaction was a significant source of variation for height as it was reported to be in the other articles.

Pre-weaning growth of calves is significantly influenced by the dam, both by the genes transmitted and by the maternal environment provided to weaning. The

influence of aging on changes in size, weight, and physiological function of the cow also influence maternal environment; therefore the influence of age of dam on birth weight and weaning weight must be considered. Koch and Clark (1955) found the largest difference for birth weight and weaning weight to be between the ages of 3 and 4 yr. It appears that applying a correction factor for ages 3, 4, and 10 yr or older would remove most of the variation due to age of dam. Marlowe et al. (1965) found age of cow to have a significant effect on calf gains except among the 7 through 11-yr-old cows. Schalles and Marlowe (1967) found that age of dam had a significant positive effect on 365-d weight, lifetime ADG, and test ADG on individually-fed bulls at Culpepper. Dam age had a highly significant effect on all live weights from birth to the end of test in all bulls weaned at 168 d of age in the study by Simm et al. (1985). The weights of the bulls increased with increasing dam age up to 5 yr. Dam age accounted for 19 to 30% of the variation in live weight, and for 10 to 20% of the variation in cumulative food intake from 245 to 400 d of age.

In general, as calves increased in age their gains decreased. Swiger et al. (1962) reported in their study that older and, to a limited extent, younger calves

gained more slowly than calves near the average age of the 130 to 200 d age period; however, their age and seasonal effects were confounded. Marlowe et al. (1965) found that ADG was not significantly different between adjacent age groups among noncreep-fed calves, but age did have a highly significant effect on ADG over the entire age range. Schalles and Marlowe (1967) found a significant negative influence of age of calf at beginning of test and 365-d weight of individually-fed bulls at Culpepper, and group-fed bulls at Front Royal. Older bulls gained faster on test at both the Culpepper and Front Royal tests. Lifetime ADG was not influenced by age at either location. Henningsson (1986) found age at start of test to have a significant effect on daily gain for Swedish Red and White bulls. He explained the effect of age at start of test on daily gain by, "the generally sigmoid shape of the growth curve, which means a lower growth rate during the early months of a young bull's life than later on. This means that daily gain of a bull which starts the test at an early age will be underestimated in comparison with a bull that is older when starting its test, because the lower daily gain early in the test period will reduce the average daily gain of the whole period."

Few researchers have reported the effects of pre-weaning performance on subsequent test performance. Schalles and Marlowe (1967) found that as pre-test ADG increased both lifetime ADG and 365-d weight also increased. The influence of pre-test ADG on test gains was not significant; however, the relationship was positive and approached significance for group-fed bulls at Front Royal. Swiger (1961) did not report on pre-test ADG, but determined that the effect of age at weaning and weaning weight as well as the effect of age at weaning on post-weaning gain to be nearly linear. He also established that bulls tend to grow at a much faster rate immediately prior to weaning than they did earlier, but this does not have a large effect on later test gains. Simm et al. (1985) reported on 3 rearing treatments: weaning bulls immediately after birth, weaning at 84 d, or at 168 d. Artificial rearing was not effective in reducing environmental variation in performance. Bulls weaned at 84 d of age were least affected by environmental factors, and performed as well as bulls weaned at 168 d of age. Earlier weaning of bulls followed by submission to central test stations may also reduce the effect of herd. There is growing evidence to indicate that central performance tests of beef bulls may be more effective if started at 2 to 3-

mo of age in order to reduce the effects of age and pre-test traits such as environment and daily gains.

Heritabilities and Correlations

Many researchers have analyzed performance data concerning weights at birth, weaning, end of test, and 365-d. Heritability estimates have subsequently been reported ranging from .00 to over 1.00. Knapp, Jr. and Nordskog (1946) were the first to report heritability estimates of economically important traits in beef cattle. Their estimates were calculated for each trait using 3 methods: inter-year correlation between half-sibs, regression of progeny average on sire, and regression of progeny average on sire within year of sire birth. The following heritability estimates from the 3 methods were reported: for birth weight .23, .42, .34; for weaning weight .12, .00, .30; and for final weight .81, .69, .94, respectively. Knapp, Jr. and Clark (1950) revised these estimates utilizing half-sib correlations and reported heritabilities of .53, .28, and .86 for birth weight, weaning weight (age corrected), and 15-mo final feedlot weight, respectively. Other heritability estimates for birth weight (BW), weaning weight (WW), and final feedlot weight (FFW) are shown in Table 1. Woldehawariat et al. (1977) summarized reported estimates to obtain overall

unweighted average heritability estimates of .39, .31, and .47 for birth weight, weaning weight, and final feedlot weight, respectively.

Genetic correlations between weight traits tend to be strong and positive due to many of the same genes affecting these traits and due to the fact that many of these involve part-whole relationships. Koch and Clark (1955) stated that the genetic correlation between birth weight and weaning weight (.63) indicated that many of the same genes which determine prenatal growth also affect postnatal growth. The genetic correlation between birth weight and yearling weight (.40) and between weaning weight and yearling weight (.54) are slightly less due to the effects of the environment under which the calf is raised. Many other estimates of genetic correlations between birth weight and weaning weight, birth weight and yearling weight, and weaning weight and yearling weight have been reported such as .40, .37, and .51 (Koch and Clark, 1955) and .31, .36, and .87 (Swiger, 1961). Brinks et al. (1962) reported correlations of: .21 for birth weight and 180-d weaning weight, .75 for birth weight and final weight, and .67 for 180-d weaning weight and final weight. Brown et al. (1973) published the following correlations: .57 for 4-mo weight and final test weight, .74 for 8-mo weight and

final test weight, and .99 for 12-mo weight and final test weight. DeNise and Ray (1987) reported correlations of .98 for initial weight and final weight, .76 for 12-mo weight and 20-mo weight, 1.08 for 12-mo weight and 24-mo weight, and .97 for 20-mo weight and 24-mo weight. Woldehawariat (1977) calculated .55, .62, and .73 as overall unweighted average genetic correlations for birth weight and weaning weight, birth weight and final feedlot weight, and weaning weight and final feedlot weight, respectively. Although these genetic correlations range considerably, one must notice that all estimates are moderately strong and positive, further supporting Koch and Clark's claim that many of the same genes influence both prenatal and postnatal growth.

Not only are genetic correlations between subsequent weights important, but the relationships between gains and weights and subsequent gains have been of considerable interest to researchers over the years. Koch and Clark (1955) were among the first to report genetic correlations between birth weight and gain from birth to weaning (.46), birth weight and gain from weaning to yearling (.06), weaning weight and gain from birth to weaning (.98), weaning weight and gain from weaning to yearling (-.03), yearling weight and gain

from birth to weaning (.51), yearling weight and gain from weaning to yearling (.83), and gain from birth to weaning and gain from weaning to yearling (-.05). Many other researchers have looked at similar genetic correlations and made estimates. Swiger (1961) reported low, positive correlations (.02 to .28) between both birth weight and weaning weight and subsequent test period average daily gains. Correlations between weights and the gain period immediately preceding were consistently high (.54 to .99), partially due to the existing part-whole relationships (Koch and Clark, 1955; Brinks et al., 1962; Swiger et al., 1962; Brown et al., 1973; DeNise and Ray, 1987). Consecutive gain periods showed low, negative correlations, ranging from -.06 to -.31, illustrating the variation in the weight conditions expressed by animals at different weighing times (Koch and Clark, 1955; Brinks et al., 1962; Swiger et al., 1962; Crawford, Jr. et al., 1967; Tong, 1982). Woldehawariat (1977) calculated, from all reported estimates, unweighted average genetic correlations of .34, .51, .99, .32, .22, .67, and .82 for birth weight and pre-weaning gain, birth weight and feedlot gain, weaning weight and weaning to yearling gain, weaning weight and feedlot gain, pre-weaning gain and feedlot

gain, pre-weaning gain and final weight, and feedlot gain and final weight, respectively.

Along with genetic correlations of weights and gains, estimates of heritability for rate of gain can be calculated using gain ratios or average daily gains. The majority of the literature reviewed used average daily gains to estimate rate of gain heritabilities. A summary of the reported estimates is in Table 2.

Although weights and gains are the primary traits of interest, many other traits are commonly evaluated during bull performance tests. Scrotal circumference, hip height or frame score, ribeye area, and backfat thickness have also been measured. Many genetic correlations between these secondary performance traits and weight and gain data have been reported by Melton et al. (1967) including: $-.55$ for ribeye area and feed conversion, $.44$ for testicle weight and feed conversion, and $-.37$ for testicle weight and weight of the round. Brown et al. (1973) reported correlations of $.77$, 1.15 , $.71$ for 4, 8, and 12-mo hip height and pre-weaning gain in Hereford bulls; $.87$, $.83$, $.93$ for 4, 8, and 12-mo hip height and pre-weaning gain in Angus bulls; $.83$, $.97$, 1.01 for 4, 8, and 12-mo hip height and test gain in Hereford bulls; $.33$, $.57$, $.93$ for 4, 8, and 12-mo hip height and test gain in Angus bulls; $.76$, $.78$, $.99$ for

4, 8, and 12-mo hip height and final test weight in Hereford bulls; and .59, .86, .79 for 4, 8, and 12-mo hip height and final test weight in Angus bulls, respectively. Correlations between on-test hip height and on-test scrotal circumference of .43, .49, .32, .35, and .56, and for off-test hip height and off-test scrotal circumference of .25, .33, .28, .23, and .12 for Hereford, Polled Hereford, Angus, Brangus, and Charolais bulls, respectively; between on-test hip height and ADG (.14), off-test hip height and ADG (.33), and between ribeye area and off-test weight (.73) for all breeds were reported by Baker et al. (1982). Latimer et al. (1982) calculated correlations of -.01 and -.02 for 205-d weight and ribeye area and yearling scrotal circumference, and low, positive correlations (.08 to .35) between growth and live-estimated carcass traits with weaning and yearling scrotal dimensions. Comerford et al. (1988) reported the most recent estimates of .92, .22, and -.44 for genetic correlations between weaning weight and yearling hip height, yearling weight and yearling hip height, and feedlot daily gain and yearling hip height, respectively. Due to the variability in data available, it is not clear which is the most appropriate genetic correlation estimate to utilize. However, heritability estimates only range from .24 to

.85 for the secondary performance traits. Estimates for these traits have included: .68 for ribeye area by Knapp, Jr. and Clark (1950); .38 and .72 for backfat thickness and ribeye area by Shelby et al. (1955); .60 and .38 for weaning and yearling scrotal circumferences by Latimer et al. (1982); .24, .49, .32, and .60 for hip height, and .41, .47, .56, and .45 for scrotal circumference by Nelsen et al. (1986); .28 for backfat thickness by McWhir and Wilton (1987); and .85, .49, and .53 for hip height, backfat thickness, and scrotal circumference by deRose et al. (1988).

Traits of Interest

Many selection traits are of interest to cattlemen. Traits of particular interest in bulls are: weight, average daily gain on feed, weight per day of age, 365-d weight, scrotal circumference, hip height or frame score, and carcass traits such as ribeye area and backfat thickness. Few bull tests measure individual feed consumption; however, Grizzle and Kincaid (1954) and Silcox (1980) both analyzed individual feed consumption and rate of gain and concluded that rate of gain is a more effective measure of efficiency than ratio of gain to feed consumption. Pounds of feed per pound of gain as a measure of efficiency in feeding trials may be misleading. As a result most test

stations use average daily gain (ADG) to evaluate feed efficiency since it is a much cheaper and easier trait to measure.

Duration of Test

Most bull performance tests last 140 d in length. Dinkel (1958) first reported heritability estimates for test period ADG calculated by the paternal half-sib method of .45, .52, and .65 for 140, 168, and 196-d test periods, respectively. Dinkel concluded that selection on the basis of 140-d gain would make 79% (depending on style used) of the improvement expected from the use of 196-d gain, and selection on 168-d gain 84%. However, selection on 140-d gain would make 94% of the improvement expected by selecting on 168-d gain. In 1959 Dinkel revised his heritability estimates for the 140, 168, and 190-d test period gains to .39, .45, and .43, respectively. Swiger and Hazel (1961) reported high genetic covariances between subsequent gain periods which suggest that selection for weight at a year of age may be made earlier in an animal's lifetime with little loss of efficiency of selection. Their results also suggest that post-weaning evaluation periods may be shortened without serious loss of efficiency in selection for gaining ability. Swiger et al. (1961) concluded from the Fort Robinson analysis that

additional information about genetic values for final weight and feedlot gain which resulted from adding subsequent 56-d period data justified feeding at least 168 d. Buchanan and McPeake (1986) calculated correlations of greater than .80 between 84, 112, and 140-d ADG values, which they felt indicated that shorter test period ADG was nearly as useful as the ADG calculated from the full 140-d test period.

Summary

Although much research has been completed on bull test performance, much more is needed. Until now most experiments have evaluated small numbers of bulls and limited breeds. There is a definite need for the analysis of large numbers of bulls from different breeds over many years. Such a large study would allow for the separation of more effects such as season, location, and percentage and polled character within breed. Genetic trends within and across breeds would also be more effectively analyzed due to the greater number of bulls across a longer time span. Preliminary research by Buchanan and McPeake (1986) compared measurement of average daily gain over the entire 140-d test to measuring average daily gain for 112 or 84 d. High, positive correlations were calculated between 84, 112, and 140-d ADG values. These values were reported as

evidence that shorter test period ADG was nearly as useful as the full 140-d ADG. Correlations between subsequent gain periods are expected to be high and positive since shorter periods are part of the longer periods. Subsequent ADG values are involved in a part-whole relationship and are therefore closely correlated. Further research must be completed in order to validate the recommendation that shorter tests are as accurate as the current 140-d tests before changes can be implemented at central test stations. A more objective analysis of the validity of shorter tests would involve rank correlation analysis of bulls within each gain period. If the ranking of the bulls did not significantly change then it could be concluded that shorter test periods are as accurate as the 140-d test period.

TABLE 1. HERITABILITY ESTIMATES OF WEIGHT TRAITS

Author and Date	BW ^a	WW	FFW
Shelby et al. (1955)	.72	.23	.84
Koch & Clark (1955)	.35	.24	.47
Koch & Clark (1955)	.44	.11	.16
Shelby et al. (1960)			.77
Swiger (1961)	.22	.25	.47
Brinks et al. (1962)		.48	
Swiger et al. (1962)	.30, .37	.02, .20	
Gacula & Brown (1963)			.21
Nelsen et al. (1986)	.39, .50	.25, .34	.53, .47, .62, .41

^aBW = Birth Weight, WW = Weaning Weight, FFW = Final Feedlot Weight.

TABLE 2. A SUMMARY OF RATE OF GAIN HERITABILITY ESTIMATES

Author and Date	B.W.Gain ^a	W.Y.Gain	O.Gain	F.Gain
Knapp & Nordskog (1946)			.98, .46	
Knapp & Clark (1950)				.65
Kincaid et al. (1952)			.22	
Koch & Clark (1955)	.21	.39		
Shelby et al. (1955)			.60	
Warwick & Cartwright (1955)			.38	
Shelby et al. (1960)				.46
Swiger (1961)				.14
Brinks et al. (1962)				.40
Swiger et al. (1962)	-.02, .14			
Gacula & Brown (1963)			.77	
Nelsen et al. (1986)	.27, .35			
McWhir & Wilton (1987)			.70	
deRose et al. (1988)	.25		.44	
Woldehawariat (1977 summary)	.25			.45

^aB.W.Gain = Pre-weaning ADG, W.Y.Gain = ADG from Weaning to Yearling, O.Gain = Overall 140-d test ADG, F.Gain = Final feedlot ADG.

MATERIALS AND METHODS

This study was designed to evaluate bull test performance data collected at Kansas central testing stations over 16 yr. The first Kansas Bull Test started at Beloit in June, 1971. A second test was added in 1975 at Yates Center and was moved to Potwin in 1982. In the 50 tests completed through 1986, 11,494 bulls were evaluated representing 32 breeds. Table 3 shows the distribution of the number of bulls by breed and location of test.

Bulls (average 224 d of age) were delivered to the test stations about 3 wk before start of the tests (approximately October 28 for winter tests and May 11 for summer tests) to allow for acclimation.

At arrival approximately 50 bulls of the same breed were placed in dirt lots with approximately 38.5 sq. meters pen space per bull. This is similar pen space allotted in most Kansas feedlots. Lots had a 10-12% slope for drainage, no shade or wind protection, and were surrounded by pipe and(or) cable fencing. Bulls were bunk-fed a high roughage starting ration for the first 3 wk which was gradually increased in NE through the 140-d test period. The nutrient composition of sample rations are listed in Table 4. Weights were taken on 2 consecutive days and averaged to obtain the on-test weight. Bulls averaged 245 d of age and 281.7 kg at the start of the test. In

addition to the starting weight, bulls were weighed on days 56 and 112. A final weight was obtained by averaging weights from 2 consecutive days at the end of the test (140-d).

Pre-weaning and growth data were collected from June, 1971 to 1986 at Beloit, between 1975 and 1981 at Yates Center, and from 1982 to 1986 at Potwin. Simple means of the pre-test performance traits of 7 breeds with a sample of over 400 bulls are shown in Table 5. Data other than growth traits that were recorded include: 112-d hip height (HH) since 1974, 140-d ribeye area (REA) from 1974 until 1984, 140-d backfat thickness (BF) since 1974 (measured by ultrasonic imaging), and scrotal circumference (SC) on all bulls eligible for sale since 1975. Bulls in the upper two-thirds of the test index (an average of 140-d ADG ratio and end of test WDA ratio) were eligible to sell before 1983. Since 1983 only bulls with a test index of 100 or above were eligible to sell. Bulls which indexed below 100 were not auctioned at the completion of the test, but were returned to their owners. Weight per day of age (WDA), average daily gain (ADG), 365-d weight (AYW), and frame scores (FR) were calculated for all bulls completing the test. The BIF recommended calculations for these growth traits were used (BIF Guidelines, 1986).

Data analyses were conducted using least squares analysis of variance. Only 7 breeds with at least 400 bulls well distributed over the test period were included in the least squares analyses. The model included: birth year, breed, season of test, and test location as main effects and a regression of on-test age. Breed percentage within breed and polled character within breed were added as main effects for a separate analysis of Charolais, Gelbvieh, Limousin, and Simmental bulls.

Selling price of the 5,854 bulls which sold between 1971 and 1986 was recorded in combination with the performance data. Potential buyers were provided with a sales catalog prior to each sale. Information presented in the catalog included: bull identification, owner, a 2-generation pedigree, birth date, and breed which included percentage and a notation regarding the polled character of the bull. Performance data available in the sales catalog included: birth weight (BW), 205-d adjusted weaning weight (AWW), 205-d weaning weight ratio (WWR) and number of contemporaries, 140-d ADG and ratio, final test weight, 140-d WDA and ratio, 365-d weight (AYW), scrotal circumference (SC), backfat thickness (BF), frame score (FR), and sale index.

Simple correlations as well as rank correlation analyses were calculated between 112 and 140-d average

daily gains. The results of these analyses were used to determine whether the rank of bulls within their breed changed significantly from d 112 to d 140. If ranks were not significantly different at these periods then reducing the length of bull tests to 112 d would save money and not forfeit any accuracy in the prediction of subsequent bull performance. However significant rank changes would dictate the necessity of longer test periods.

TABLE 3. NUMBER OF OBSERVATIONS BY BREED AND LOCATION

BREED	TOTAL NUMBER	LOCATION		
		Beloit	Potwin	Yates Center
Amerifax	22	15	7	
Angus	2,282	1,796	296	190
Beef Friesan	15	15		
Beefalo	4	4		
Beefmaster	3			3
Blonde d'Aquitaine	18	12		6
Brangus	45	26	6	13
Charolais	745	611	77	57
Chianina	152	126	19	7
Galloway	10	10		
Gelbray	8	5	3	
Gelbvieh	446	347	95	4
Hereford	991	776	151	64
Herfex	6		6	
Limousin	448	279	152	17
Maine-Anjou	136	79	43	14
Marchigiana	19	15	3	1
Milking Shorthorn	3	2	1	
Murray Grey	31	15		16
Norwegian Red	23	23		
Polled Hereford	757	537	85	135
Polled Shorthorn	3	3		
Red Angus	28	12	4	12
Red Poll	9	5		4
Romagnola	7	7		
Salers	12	10	2	
Santa Gertrudis	16	12	4	
Shorthorn	19	19		
Simbrah	7	4	3	
Simmental	5,189	3,885	767	537
South Devon	20	11	4	5
Tarentaise	20	16		4
TOTAL	11,494	8,677	1,728	1,089

TABLE 4. NUTRIENT COMPOSITION OF SAMPLE RATIONS (D.M. BASIS)

	NE _m ^a	NE _g	CP
<u>1971</u>			
Starting Ration	68	42	12.68
Intermediate Ration	72	46	12.57
Final Ration	75	48	12.45
<u>1978</u>			
Starting Ration	68	39	12.70
Intermediate Ration	71	43	12.52
Final Ration	74	46	12.36
<u>1980</u>			
Starting Ration	78	46	13.56
Intermediate Ration	82	49	13.46
Final Ration	86	52	13.38
<u>1982</u>			
Starting Ration	80	48	13.98
Intermediate Ration	86	53	13.83
Final Ration	90	57	13.73
<u>1985</u>			
Final Ration	84	52	13.00

^aNE_m: Net energy for maintenance (Mcal/cwt), NE_g: Net energy for gain (Mcal/cwt), CP: Crude protein content (%).

TABLE 5. SIMPLE MEANS AND STANDARD DEVIATIONS OF PRE-TEST PERFORMANCE TRAITS BY BREED

	Angus	Charolais	Gelbvieh	Hereford	Limousin	Polled Hereford	Simmental
BW ^a	35.4 (4.4)	40.2 (6.4)	39.8 (4.5)	38.4 (4.0)	36.3 (3.3)	36.3 (4.2)	41.8 (4.3)
AOD	5.8 (2.7)	6.1 (2.7)	5.0 (2.4)	5.6 (2.4)	6.0 (2.7)	5.8 (2.6)	5.2 (2.4)
WW	242.2 (32.9)	264.0 (37.6)	268.6 (34.7)	238.0 (35.1)	244.8 (35.9)	228.3 (30.4)	264.3 (40.7)
AWW	248.6 (29.0)	284.0 (33.9)	289.3 (33.8)	247.1 (32.8)	266.2 (36.4)	237.6 (30.5)	277.7 (38.3)
WWR	104.6 (8.4)	104.2 (8.9)	102.8 (6.6)	108.2 (9.9)	102.5 (7.8)	105.3 (8.4)	103.5 (7.7)
WA	204.4 (22.9)	192.4 (21.0)	193.9 (22.1)	205.4 (23.8)	192.5 (25.7)	202.3 (20.9)	199.7 (23.3)
WDA-W	1.2 (.1)	1.4 (.2)	1.4 (.2)	1.2 (.2)	1.3 (.2)	1.1 (.1)	1.3 (.2)
OTW	270.2 (35.4)	295.1 (41.5)	293.1 (40.5)	262.2 (35.3)	268.1 (38.9)	257.7 (32.8)	293.5 (41.8)
OTA	250.4 (24.2)	240.6 (24.8)	238.2 (20.6)	247.2 (24.1)	238.8 (26.4)	246.9 (21.7)	243.1 (23.0)
WDA-OT	1.1 (.1)	1.2 (.1)	1.2 (.1)	1.1 (.1)	1.1 (.1)	1.0 (.1)	1.2 (.1)

^aBW = Birth Weight (kg), AOD = Age of Dam (yr), WW = Actual Weaning Weight (kg), AWW = Adjusted Weaning Weight (kg), WWR = Weaning Weight Ratio, WA = Age at Weaning (d), WDA-W = Weight per day of age at Weaning (kg/d), OTW = On-Test Weight (kg), OTA = Age On-Test (d), WDA-OT = Weight per day of Age On-Test (kg/d).

RESULTS AND DISCUSSION

Significant effects of year, season of year, test location, breed, and age of dam were revealed by the least squares analyses for most traits. The effects of percentage of breed and polled character within breed had much less influence on most traits.

Pre-Test Performance Traits

Table 6 shows least squares means and standard errors by birth year, season of year, test location, breed, and age of dam. The number of observations used for each analysis is listed at the top of each column. Weight traits including actual weaning weight (WW), adjusted 205-d weaning weight (AWW), and on-test weight (OTW) have significantly increased over the past 16 years. It must be noted however that due to missing observations, birth weight (BW) can only be analyzed from 1975 to 1986. Prior to 1975 very few producers recorded birth weights. Increased emphasis has been placed on birth weights over the past years. From 1975 to 1981, birth weights increased in a linear fashion (.487 kg/yr) resulting in a 2.92 kg increase in average birth weight. Since 1981, selection emphasis on birth weight has been changed from increasing to moderating in order to reduce calving difficulties. Selection pressure on other weights, however, continues to

be for increased weights both at weaning and on-test. Actual weaning weight (WW), adjusted 205-d weaning weight (AWW), and on-test weight (OTW) all show similar trends of near linear increases over the past 16 years. Results show average annual increases of 3.37 kg, 3.03 kg, and 2.26 kg for WW, AWW, and OTW, respectively. Coupled with the average annual decrease of .59 d in weaning age (WA), this table clearly illustrates the industry's move toward heavier bulls at earlier ages. These annual trends agree with those genetic trends presented in the 1989 Hereford, Limousin, and Angus sire summaries. Hereford and Limousin sire summaries express increasing yearly trends in these weights as increased Expected Progeny Differences (EPD). The Angus Association shows a .45 kg/yr (1 lb/yr) increase in birth weight from 1977 until 1986, and an overall increase of 75 lb (34.02 kg) and 139 lb (63.05 kg) in weaning weight and yearling weight, respectively, from 1972 until 1986.

Spring born bulls, those on winter tests, had significantly heavier birth weights, actual and adjusted weaning weights, and were older at weaning than those on summer tests. This agrees with Marlowe et al. (1965) who found that calves born during March and April made fastest gains while those born during August, September, and October were at the greatest disadvantage. Season of year

did not significantly affect weaning weight ratio or on-test weight. Test location, although significantly different for birth weight, had little effect on the other pre-test traits. This is to be expected since bulls at each location are trucked in and therefore are not necessarily native to the immediate area of the individual test and producers may have had different selection criteria for bulls entering the different tests.

The effects of breed were significant for the majority of the pre-test performance traits. Angus bulls had the lightest birth weights and were oldest at weaning while having the second lightest actual and adjusted weaning weights. Hereford and Limousin bulls significantly outweighed Polled Herefords at both weaning and start of test. Charolais and Simmental bulls were heaviest at all pre-test weights while Hereford and Gelbvieh bulls were lighter at birth and similar to Limousin bulls at weaning and on-test. Weaning age and weaning weight ratios present substantial insight as to the rank of the bulls within their originating herds. Lower weaning weight ratios signify bulls which are closer to average for their respective herd. Charolais, Limousin, Gelbvieh, and Simmental bulls were younger at weaning and had lower weaning weight ratios (WWR) than any of the other breeds. Hereford, Polled Hereford, and Angus bulls had

significantly larger weaning weight ratios. From this we note that bulls of the latter 3 breeds must be more superior within their herd.

Age of dam had a significant effect on most of the weight traits. The largest difference in birth weight was for 2-yr-old dams. Birth weights increased significantly until dams reached 10 yr. Actual weaning weights followed a similar trend, while on-test weights showed less variation due to age of dam which is in agreement with other literature (Koch and Clark, 1955; Marlowe et al., 1965; Swiger et al., 1962). Less difference between on-test weights illustrate the effects of compensatory gains which occur after weaning. Weaning age significantly decreased as dam age increased from 2 to 4. Adjusted weaning weights and weaning weight ratios did not differ significantly across dam age groups. This is to be expected since an adjustment factor for age of dam is included in the calculation of adjusted weaning weights and ratios. The linear regressions of all pre-test performance traits on on-test age were highly significant except adjusted weaning weight as shown in Table 7. For each additional day older at start of test bulls were lighter at birth, had heavier actual weaning and on-test weights, lighter adjusted weaning weights, and smaller weaning weight ratios. Bulls 30 days older than average would be

expected to have 20.16 kg and 27.09 kg heavier actual weaning weights and on-test weights, respectively.

Least squares means and standard errors of pre-test performance traits by percentage of breed and polled character within breed are in Table 8. Effects of percentage of breed on birth weight and actual weaning weights were generally small. Percentage had no significant effect on on-test weight. Polled character within breed was only significant for adjusted weaning weight in Gelbvieh bulls and for on-test weight in Charolais and Simmental bulls with polled bulls significantly heavier in each case. Percentage and polled character has not been previously analyzed since in most cases these effects are confounded with breed effects.

Average Daily Gains

In general, average daily gains (ADG) during all stages of test increased from 1970 until 1986. Least squares means and standard errors for average daily gains are given in Table 9. Year of test had a significant effect on ADG across the entire test period. Bulls tested in 1972 and 1978 had the lowest ADG throughout the test while bulls tested in 1985 had the highest gains. Significant year effects are in general agreement with other literature (Brown et al., 1981; deRose and Wilton, 1986; Koots et al., 1988; Tong, 1982). Season of year also

had significant effects on ADG. Bulls on summer test outgained winter tested bulls across the test period. Differences were attributable primarily to harsher environmental conditions for bulls on winter tests. Although bulls were fed ad-libitum, maintenance requirements were higher in winter thus less energy was available for gains. Location had a significant effect on average daily gains for all periods except 56-140 d. Bulls at Potwin and Beloit generally outgained bulls at Yates Center; however, it must be noted that the Yates Center test only ran from 1975 until 1981 when it was moved to Potwin. Differences noted could be due to different weather conditions and differences in the test management at each location. Brown and Keaton (1975) reported no significant effects of location on average daily gains. Breed differences were highly significant for all test gain periods. Average daily gains ranged from 1.29 to 1.59 kg/d. Polled Hereford, Hereford, Angus, and Limousin bulls were the slowest gainers and Charolais and Simmental fastest, with Gelbvieh intermediate. These breed differences agree with previous studies on ADG (Brown and Keaton, 1975; Brown et al., 1986; Koots et al., 1988).

Linear regressions of average daily gains on on-test age, frame score, and frame score² are in Table 10. Only regressions of 0-56 d, 0-112 d, and 0-140 d average daily

gains on on-test age were highly significant. All average daily gain regressions on frame score were also highly significant as were regressions on frame score² for all gain periods except 112-140 d. Average daily gains were further analyzed by percentage of breed and polled character within breed and the least squares means and standard errors are reported in Table 11. There were few significant effects of percentage of breed on average daily gains. Percentage Simmental bulls showed the largest differences with Gelbvieh bulls showing differences only at 0-56 d and 0-140 d gains. Percentage Charolais bulls showed differences in gains toward the end of the test. No significant effects of percentage of breed were found in the Limousin bulls. Polled character had no significant effect on average daily gains for any of the 4 breeds analyzed.

Weight Per Day of Age

Weight per day of age (WDA) was analyzed from 1973 until 1986 since calving data prior to 1973 was not available. Least squares means and standard errors of WDA are in Table 12. Pre-weaning WDA (WDA1) was calculated from birth until weaning while on-test WDA (WDA2) was calculated from birth to start of test. All weight per day of age values were slightly affected by year. Although trendless, the effect of year on WDA indicated that gain

patterns varied from year to year. Fluctuations in WDA gain patterns were also reported by Patterson et al. (1982) when 26 yr of Alabama bull test data were analyzed. These variations could partially be due to environmental differences and(or) differences in the bulls tested.

Season had a significant effect on WDA during all gain periods. Bulls on winter test had heavier pre-weaning weight per day of age. Spring born bulls had heavier pre-weaning gains since their dams probably had more energy available to produce milk and needed less energy for maintenance. Winter tested bulls had lower weight per day of age on test due to harsher environmental conditions during the test period requiring more energy for maintenance and less energy available for gain.

Location effects are a composite of many different genetic and environmental components. Cain and Wilson (1982) reported location effects as environmental factors such as diet composition, climate, and type of facilities used. Diet composition differed between locations which may have accounted for differing gains. Although energy content was approximately the same across locations, ingredients were changed depending on the availability and price at each location. Differing ingredients may have affected palatability thus causing decreased intake which resulted in lower weight per day of age.

Simmental and Limousin bulls had the lowest WDA throughout the pre-test period. Angus, Hereford, and Polled Hereford bulls had the highest WDA across all periods, while Charolais and Gelbvieh bulls were intermediate throughout all periods. All weight per day of age regressions on frame score and frame score² (Table 13) were highly significant except 140-d weight per day of age on frame score².

Least squares means and standard errors for weight per day of age by percentage of breed and polled character within breed are in Table 14. Percentage of breed showed little effect except for purebred Gelbvieh, Limousin, and Simmental bulls which tended to have the lowest WDA across the test period. Polled character within breed showed significant effects on Gelbvieh and Simmental bulls only. Horned Charolais and polled Simmental bulls had heavier weight per day of age across the entire test period, while polled Gelbvieh bulls tended to gain faster. Differences between Limousin bulls were not significant.

Other Performance Traits

Least squares means and standard errors of 365-d weight (AYW), ribeye area (REA), backfat thickness (BF), scrotal circumference (SC), frame score (FR), and price (PR) are listed in Table 15. Adjusted yearling weights increased significantly from 1972 until 1977, were low in

1978 and continued to increase through 1986. These trends in yearling weight follow the industry's selection pressure for increased cattle size from year to year. Brown et al. (1986) reported similar trends in final weight while Koots et al. (1988) showed increasing trends in end-of-test weights from 1965 to 1986. Johnson (1986) found off-test weight significantly increased from 1981 to 1985 while 1985 to 1987 were all similar. Bulls tested in winter were lighter at yearling, a result of more harsh environmental conditions which caused increased maintenance requirements. Significant location effects were also found. Polled Hereford bulls were lightest at yearling followed by Angus and Hereford bulls. Charolais and Simmental bulls were heaviest at yearling while Limousin and Gelbvieh bulls were intermediate.

Ribeye area, measured only from 1973 until 1984, decreased significantly until 1979 when an increase of 6.72 cm^2 was reported in a single year. Significant decreases in ribeye area occurred again from 1980 until 1983 when another significant increase was reported. Johnson (1986) found ribeye area estimates largest in 1986 and smallest in 1981 with other years intermediate. Backfat thickness, measured from 1973 until 1986, showed a generally decreasing trend although yearly changes varied over the time period. Backfat thickness estimates were reduced over

the 13 yr period by .26 cm, a decrease of 37%, a result of continued selection for leaner cattle by the industry. Johnson (1986) reported similar trends in fat thickness with bulls tested in 1987 having significantly less ribfat than bulls tested in any other year.

Scrotal circumference, measured from 1974 until 1986, significantly increased from 1974 until 1984 resulting in an increase of 4.24 cm. Bulls tested in 1985 showed a significant decrease of 1.75 cm, to a value similar to bulls tested in 1979. Scrotal circumference increased slightly from 1985 until 1986. Johnson (1986) found an increase in scrotal circumference from 1981 to 1984 with bulls tested from 1984 until 1987 being similar. Frame score, calculated from 1973 until 1986 showed a near linear increase of .18 frame score units per year. Frame score was calculated using hip height measured on d 112 of the test period. Increased frame score over the years reflects the industry's emphasis on taller cattle at an earlier age. Bulls tested in 1986 had significantly lower frame scores than those tested in 1985, possibly a result of the recent switch toward more moderate cattle.

Price followed an increasing trend from 1970 until 1974 when cattle prices dropped considerably due to the recession and drought. Another increasing price trend began in 1975 and ended in 1978 with the highest average

sales price recorded. Prices in 1979 through 1982 were similar with slight decreases occurring yearly through 1985, when cattle prices across the industry dropped considerably. A highly significant increase of \$268.06 was noted from 1985 until 1986 signifying renewed stability in cattle prices throughout the industry. Inflation and the overall cattle market were the major sources of change in price through the years. Increasing price trends may also have resulted from the production of more acceptable cattle. As producers continue to produce leaner, faster growing cattle, prices should continue to increase until the supply of bulls meet the demand.

Significant effects of season of year were found on ribeye area, scrotal circumference, frame score, and sales price. Bulls on winter test had significantly larger ribeye areas (1.53 cm^2), larger frame scores (.07 score units), lower adjusted yearling weights (7.19 kg), and were sold at higher prices (\$112.55) than bulls on summer test. Scrotal circumference was significantly larger (.40 cm) on summer tested bulls while backfat thickness was the same over both test seasons. Test location had little effect on ribeye area, backfat thickness, scrotal circumference, and frame score; however large differences in sales price resulted. Differences are likely to be due to climatic conditions and diet composition. Bulls sold at Beloit

averaged \$307.29 and \$187.02 more than bulls at Potwin and Yates Center, respectively. Breed effects were significant for ribeye area, backfat thickness, scrotal circumference, frame score, and sales price. Angus, Hereford, and Polled Hereford bulls had the smallest ribeye areas and frame scores, and greatest backfat estimates. Charolais and Limousin bulls had the largest ribeye areas, smallest scrotal circumferences,, and intermediate frame scores. Simmental and Gelbvieh bulls had intermediate ribeye areas and backfat estimates with the largest frame scores. Angus, Gelbvieh, and Simmental bulls had the largest scrotal circumferences.

Sales price was significantly affected by breed. Polled Hereford and Hereford bulls averaged significantly less than any other breed, \$682.23 and \$758.93, respectively. Gelbvieh and Simmental bulls were sold for the highest prices averaging \$1065.96 and \$1000.83 while Limousin, Angus, and Charolais were intermediate. These breed differences are in general agreement with Johnson (1986). Slower growing cattle such as Polled Hereford, Hereford, and Angus used less of their energy for growth resulting in greater backfat estimates.

Linear regressions of ribeye area, backfat thickness, and scrotal circumference on on-test age and adjusted yearling weight were highly significant and are in Table

16. Regressions of adjusted yearling weight, backfat thickness, and scrotal circumference on frame score were also highly significant while frame score had only a slight effect on ribeye area. Ribeye area and backfat thickness regressed on 140-d average daily gain were highly significant while scrotal circumference was not significant. These regression coefficients are in general agreement with other literature.

Table 17 lists the least squares means and standard errors of the other performance traits by percentage of breed and polled character within breed. Percentage of breed and polled character within breed had significant effects only on sales price. 75% Charolais bulls significantly outpriced all other Charolais bulls while the price of the other breeds increased significantly as percentage increased. Significantly higher prices were paid for polled Charolais, Gelbvieh, and Simmental bulls. Polled Limousin bulls were sold at higher prices than horned Limousin bulls, however the difference was not significant.

Factors Affecting Sales Price

Differences in sales price reflect the emphasis of the industry for larger, leaner, growthier bulls at earlier ages. Bulls having smaller frames and ribeye areas with greater backfat estimates such as Angus, Polled Hereford,

and Hereford bulls are less desirable and therefore sell at significantly lower prices than do larger framed, heavier muscled bulls with smaller backfat estimates such as Gelbvieh and Simmental bulls.

Rank Correlation Analyses of 112 and 140-d Average Daily Gains

Rank correlation analyses were conducted between 112 and 140-d average daily gains to determine the percent of information present when selecting on 112-d gain rather than 140-d gain. In order for the analyses to be completed, the original data set was divided into smaller subsets. The separation of 4 yr test periods at a single location within a breed resulted in 47 separate data sets. These sets were each analyzed and subsets with similar correlations were pooled. All subsets of Gelbvieh, Limousin, and Polled Hereford bulls were pooled; however significant differences in correlation estimates within Angus, Charolais, Hereford, and Simmental prevented pooled estimates.

Pooled estimates of the rank correlation for Gelbvieh, Limousin, and Polled Hereford bulls indicated that selection on 112-d gain would only have 80.1% of the information present when selecting on 140-d gain. Similar estimates were obtained from the other breed analyses which included: estimates of only 75.3, 77.9, 73.1, and 79.0%

when using Beloit data on Angus, Charolais, Hereford, and Simmental; 76.7, 81.1, 75.5, and 64.2% for Potwin data on Angus, Charolais, Hereford, and Simmental; and 77.4, 78.3, 83.7, and 79.1% of the information available when selecting on 112-d gain rather than 140-d gain at Yates Center for Angus, Charolais, Hereford, and Simmental, respectively. Rank correlation analyses indicated that selection on the basis of 112-d gain would have only 80% of the information available if selection was based on 140-d gain. These estimates agree with the research presented by Dinkel (1958), in which he concluded that selection based on 140-d gain only made 79% of improvement while 168-d gain selection made 84% of the improvement expected if 196-d gain had been used. From these results he concluded that some advantages were obtained from longer feeding periods. Although many producers feel that central tests are currently too long, a reduction of only 28 d immediately results in only 80% of the 140-d gain information available at 112 d. With the current trends for larger framed, rapid-gaining cattle, the sacrifice of any available information cannot be recommended. These results indicated that a decrease in length of test from 140 to 112 d substantially changed the ranking of the bulls within their breed. Reduction in central bull test length from 140 to

112 d cannot therefore be recommended if the goal of the test is to determine bull performance over a longer period of time.

TABLE 6. LEAST SQUARES MEANS AND STANDARD ERRORS OF PRE-TEST PERFORMANCE TRAITS BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, BREED, AND AGE OF DAM

	BW ^a	WW	AWW	WWR	WA	OTW
Number	(7050)	(10520)	(10348)	(10091)	(10894)	(10891)
BIRTH YEAR						
70		216.62 ^d (3.56)	233.15 ^d (4.37)	109.88 ^h (1.20)	205.67 ^{gh} (3.31)	265.73 ^{ef} (2.91)
71		224.48 ^e (2.02)	241.51 ^{de} (2.31)	108.44 ^h (.68)	208.99 ^h (2.11)	272.23 ^{fg} (1.86)
72		223.91 ^e (1.80)	240.20 ^d (2.09)	106.40 ^g (.70)	206.08 ^h (2.25)	265.72 ^e (1.64)
73		219.06 ^d (1.63)	237.27 ^d (1.71)	106.51 ^g (.48)	200.43 ^{fg} (1.56)	257.36 ^d (1.54)
74		222.53 ^e (1.31)	236.57 ^d (1.32)	104.89 ^f (.35)	202.77 ^g (.98)	256.80 ^d (1.32)
75	35.14 ^d (.46)	221.69 ^{de} (1.33)	237.42 ^d (1.35)	104.68 ^f (.35)	201.34 ^g (1.01)	257.60 ^d (1.36)
76	36.33 ^e (.34)	233.51 ^f (1.38)	243.23 ^e (1.40)	103.87 ^e (.37)	200.99 ^g (1.05)	269.13 ^f (1.41)
77	36.87 ^{ef} (.26)	238.92 ^g (1.44)	245.95 ^e (1.45)	103.88 ^e (.38)	200.73 ^g (1.09)	273.46 ^g (1.46)
78	36.41 ^e (.22)	238.94 ^h (1.32)	244.09 ^e (1.33)	103.94 ^e (.35)	202.34 ^g (1.00)	275.73 ^{gh} (1.34)
79	36.99 ^f (.20)	247.50 ⁱ (1.28)	253.95 ^f (1.29)	103.38 ^d (.34)	198.28 ^f (.97)	278.32 ^h (1.30)
80	37.50 ^g (.20)	252.67 ^j (1.25)	263.20 ^h (1.26)	103.45 ^d (.33)	195.80 ^{de} (.94)	287.84 ^j (1.27)
81	38.06 ^{jk} (.20)	258.85 ^k (1.26)	267.14 ⁱ (1.28)	103.99 ^e (.34)	197.18 ^{ef} (.95)	281.55 ⁱ (1.28)
82	37.75 ^{gh} (.18)	254.28 ^j (1.09)	265.33 ^{hi} (1.11)	103.83 ^{de} (.29)	198.41 ^f (.82)	285.17 ^j (1.11)
83	37.88 ^{hi} (.18)	249.52 ⁱ (1.11)	260.07 ^g (1.12)	103.95 ^e (.29)	194.15 ^d (.83)	273.66 ^g (1.13)
84	37.94 ^{ij} (.18)	253.07 ^j (1.13)	267.08 ⁱ (1.14)	104.71 ^f (.30)	193.64 ^d (.86)	287.31 ^j (1.15)
85	38.61 ^l (.19)	266.84 ^l (1.22)	277.19 ^j (1.23)	104.50 ^{ef} (.32)	196.68 ^e (1.12)	304.04 ^k (1.24)
86	38.42 ^{kl} (.23)	270.54 ^m (1.47)	281.60 ^k (1.49)	104.60 ^f (.39)	196.19 ^e (1.11)	301.96 ^k (1.50)

TABLE 6, Continued. LEAST SQUARES MEANS AND STANDARD ERRORS OF PRE-TEST PERFORMANCE TRAITS BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, BREED, AND AGE OF DAM

	BW ^a	WW	AWW	WWR	WA	OTW
SEASON OF YEAR						
S ^b	37.16 ^m (.15)	232.74 ⁿ (.79)	243.57 ^l (.82)	104.92 ⁱ (.22)	199.22 ⁱ (.64)	273.54 ^l (.78)
W	37.49 ⁿ (.10)	248.78 ^o (.60)	261.72 ^m (.63)	105.07 ⁱ (.17)	200.74 ^j (.51)	278.65 ^l (.59)
TEST LOCATION						
B ^b	37.94 ^q (.10)	241.74 ^p (.51)	255.53 ^o (.55)	105.06 ^k (.15)	199.86 ^k (.44)	272.90 ^m (.49)
P	37.63 ^p (.15)	240.87 ^p (1.01)	251.01 ⁿ (1.03)	104.52 ^j (.28)	200.82 ^k (.84)	278.50 ⁿ (1.01)
Y	36.40 ^o (.22)	239.67 ^p (1.12)	251.40 ⁿ (1.15)	105.39 ^{kj} (.31)	199.26 ^k (.87)	276.88 ⁿ (1.12)
BREED						
AN ^b	34.46 ^f (.15)	232.02 ^f (.80)	241.10 ^q (.83)	105.39 ⁿ (.23)	205.39 ^p (.64)	266.43 ^q (.18)
CH	39.11 ^v (.26)	260.45 ^v (1.27)	273.11 ^u (1.29)	104.25 ^m (.35)	193.50 ^l (1.04)	299.53 ^t (1.23)
GV	38.28 ^u (.23)	247.25 ^t (1.60)	261.80 ^s (1.62)	103.20 ^l (.43)	197.22 ^m (1.26)	284.12 ^f (1.62)
HH	37.51 ^t (.25)	233.99 ^{r^s} (1.11)	242.76 ^q (1.16)	108.80 ^o (.31)	205.05 ^{op} (1.08)	263.68 ^p (.91)
LM	35.23 ^s (.26)	236.65 ^s (1.52)	252.36 ^f (1.57)	103.12 ^l (.42)	194.24 ^{lm} (1.24)	269.34 ^q (1.54)
HP	35.60 ^s (.24)	219.84 ^q (1.22)	230.05 ^p (1.24)	105.97 ⁿ (.34)	202.90 ^{no} (.97)	257.27 ^o (1.21)
SM	41.08 ^w (.09)	255.13 ^u (.60)	267.34 ^t (.63)	104.22 ^m (.17)	201.56 ⁿ (.50)	292.29 ^s (.60)

TABLE 6, Continued. LEAST SQUARES MEANS AND STANDARD ERRORS OF PRE-TEST PERFORMANCE TRAITS BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, BREED, AND AGE OF DAM

	BW ^a	WW	AWW	WWR	WA	OTW
AGE OF DAM (yr)						
2	37.86 ^x (.49)	244.42 ^w (3.05)	274.22 ^v (3.13)	102.99 ^p (.73)	205.04 ^s (1.03)	274.16 ^u (3.23)
3	38.89 ^y (.48)	253.35 ^x (2.99)	274.67 ^v (3.07)	102.62 ^p (.72)	198.04 ^f (.94)	283.62 ^v (3.16)
4	39.31 ^y (.48)	261.32 ^y (2.97)	274.73 ^v (3.05)	102.89 ^p (.71)	195.82 ^q (.92)	291.10 ^w (3.14)
5-9	39.99 ^z (.46)	267.40 ^z (2.82)	273.81 ^v (2.90)	102.87 ^p (.68)	196.85 ^f (.70)	295.24 ^w (2.99)
10+	39.43 ^{yz} (.61)	258.75 ^x (3.97)	270.56 ^v (4.08)	103.30 ^p (.95)	196.52 ^{qf} (1.61)	284.95 ^v (4.20)

^aBW = Birth Weight (kg), WW = Actual Weaning Weight (kg), AWW = Adjusted Weaning Weight (kg), WWR = Weaning Weight Ratio, WA = Weaning Age (d), OTW = On-Test Weight (kg).

^bS = Summer, W = Winter; B = Beloit, Kansas, P = Potwin, Kansas, Y = Yates Center, Kansas; AN = Angus, CH = Charolais, GV = Gelbvieh, HH = Hereford, LM = Limousin, HP = Polled Hereford, SM = Simmental.

^{d,e,.....,y,z} = means within effects (Birth Year, Season of Year, Test Location, Breed, Age of Dam) in the same column bearing a common superscript are not different ($P > .05$).

TABLE 7. PARTIAL REGRESSION COEFFICIENTS OF PRE-TEST PERFORMANCE TRAITS ON STARTING AGE

	BW ^a	WW	AWW	WWR	OTW
Starting Age	-.007** ^b	.672** ^b	-.119 ^b	-.333** ^c	.903** ^b
	(.0024) ^d	(.0131)	(.0134)	(.0036)	(.0131)

^aBW = Birth Weight, WW = Actual Weaning Weight, AWW = Adjusted Weaning Weight, WWR = Weaning Weight Ratio, OTW = On-Test Weight.

^bkg/d.

^cratio unit/d.

^dStandard error for partial regression coefficient estimate.

**P < .01.

TABLE 8. LEAST SQUARES MEANS AND STANDARD ERRORS OF PRE-TEST PERFORMANCE TRAITS BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED

	BW ^a	WW	AWW	WWR	WA	OTW
Number	(4382)	(4592)	(4588)	(4576)	(4429)	(4594)
CHAROLAIS						
50% ^b	42.21 ^e (2.51)	228.45 ^d (17.83)	221.24 ^d (18.30)	97.94 ^d (4.26)	181.04 ^d (12.97)	257.18 ^d (18.85)
75%		268.93 ^e (17.83)	281.05 ^e (18.30)	106.71 ^e (4.26)	199.04 ^{de} (12.97)	300.34 ^d (18.85)
88%	42.49 ^e (4.31)	275.99 ^e (30.70)	293.71 ^e (31.51)	100.19 ^d (7.33)	203.38 ^e (22.33)	301.91 ^d (32.46)
100%	39.18 ^d (.31)	260.81 ^e (1.94)	278.32 ^e (1.99)	104.29 ^e (.46)	193.62 ^d (1.42)	291.98 ^d (2.05)
HORN	40.79 ^f (1.67)	256.34 ^f (9.98)	264.89 ^f (10.24)	102.60 ^f (2.38)	195.48 ^f (7.26)	281.36 ^e (10.55)
POLL	41.80 ^f (1.73)	260.75 ^f (10.41)	272.26 ^f (10.69)	101.96 ^f (2.49)	193.06 ^f (7.58)	294.34 ^f (11.01)
GELBVIEH						
50% ^b	39.42 ^h (.53)	253.44 ^g (3.73)	267.69 ^g (3.83)	103.83 ⁱ (.89)	201.00 ^h (2.79)	283.70 ^g (3.94)
75%	37.94 ^g (.46)	260.93 ^h (3.27)	277.33 ^h (3.36)	103.86 ⁱ (.79)	197.50 ^g (2.48)	293.45 ^g (3.46)
88%	38.82 ^g (.46)	258.87 ^h (3.28)	278.46 ^h (3.37)	100.97 ^h (.79)	194.97 ^g (2.46)	289.82 ^g (3.47)
100%	39.00 ^{gh} (.46)	255.13 ^g (3.23)	277.80 ^h (3.32)	100.05 ^g (.77)	188.02 ^g (2.47)	285.30 ^g (3.41)
HORN	38.75 ⁱ (.30)	257.15 ⁱ (2.12)	273.50 ⁱ (2.18)	102.61 ^j (.51)	196.83 ⁱ (1.60)	285.57 ^h (2.24)
POLL	38.84 ⁱ (.45)	257.04 ⁱ (3.18)	277.13 ^j (3.26)	101.74 ^j (.76)	193.91 ⁱ (2.39)	290.57 ^h (3.36)

TABLE 8, Continued. LEAST SQUARES MEANS AND STANDARD ERRORS OF PRE-TEST PERFORMANCE TRAITS BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED

	BW ^a	WW	AWW	WWR	WA	OTW
LIMOUSIN						
50% ^b	35.85 ^j (1.53)	252.99 ^k (10.89)	282.45 ^m (11.18)	110.98 ^m (2.60)	160.01 ^j (9.14)	276.25 ⁱ (11.52)
75%	34.91 ^j (.61)	253.40 ^k (4.01)	274.35 ^{1m} (4.16)	103.20 ¹ (.98)	197.98 ^j (3.01)	278.12 ⁱ (4.24)
88%	35.72 ^j (.47)	249.26 ^j (3.19)	267.83 ^{k1} (3.30)	100.67 ^k (.77)	196.42 ^j (2.44)	271.29 ⁱ (3.37)
100%	34.77 ^j (.52)	245.94 ^j (3.64)	262.49 ^k (3.76)	100.68 ^k (.88)	189.60 ^j (2.90)	263.67 ⁱ (3.85)
HORN	35.35 ^k (.51)	248.07 ¹ (3.53)	269.09 ⁿ (3.63)	104.08 ⁿ (.85)	186.14 ^k (2.86)	273.19 ^j (3.73)
POLL	35.28 ^k (.61)	252.73 ¹ (4.34)	274.47 ⁿ (4.48)	104.18 ⁿ (1.04)	185.86 ^k (3.50)	271.48 ^j (4.59)
SIMMENTAL						
50% ^b	40.06 ¹ (.32)	249.62 ^m (2.23)	267.47 ^o (2.29)	104.15 ^q (.53)	204.13 ^m (1.62)	289.20 ^k (2.35)
75%	40.79 ¹ (.21)	262.83 ⁿ (1.43)	279.40 ^p (1.47)	103.31 ^p (.34)	199.60 ¹ (1.05)	295.49 ^k (1.51)
88%	41.46 ¹ (.19)	265.65 ⁿ (1.32)	281.72 ^p (1.35)	103.07 ^p (.31)	199.58 ^m (.97)	295.68 ^k (1.39)
100%	41.57 ¹ (.18)	270.47 ⁿ (1.29)	286.32 ^p (1.32)	102.07 ^o (.31)	199.19 ^m (.96)	299.69 ^k (1.36)
HORN	40.95 ^m (.17)	261.32 ^o (1.17)	277.98 ^q (1.20)	103.50 ^r (.28)	200.42 ⁿ (.86)	293.54 ¹ (1.24)
POLL	40.99 ^m (.20)	262.96 ^o (1.36)	279.47 ^q (1.40)	102.79 ^r (.33)	200.83 ⁿ (1.00)	296.48 ^m (1.44)

^aBW = Birth Weight (kg), WW = Actual Weaning Weight (kg), AWW = Adjusted Weaning Weight (kg), WWR = Weaning Weight Ratio, WA = Weaning Age (d), OTW = On-Test Weight (kg).

^b50% = Halfblood, 75% = 3/4 Blood, 88% = 7/8 Blood, 100% = Purebred; HORN = Horned, POLL = Polled.

d, e, ..., q, r = means within percentage of breed and polled character (HORN, POLL) within a breed in the same column bearing a common superscript are not different ($P > .05$).

TABLE 9. LEAST SQUARES MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS DURING TEST PERIOD BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, AND BREED

	0-56d ^a	0-112d	56-112d	56-140d	112-140d	0-140d
Number	(10887)	(10882)	(10880)	(10873)	(10875)	(10878)
BIRTH YEAR						
70	1.41 ^{ij} (.03)	1.38 ^{gh} (.02)	1.34 ^g (.03)	1.22 ^e (.02)	0.98 ^{de} (.04)	1.30 ^f (.02)
71	1.34 ^h (.02)	1.40 ^h (.01)	1.45 ^h (.02)	1.38 ⁱ (.01)	1.25 ^h (.03)	1.37 ^{gh} (.01)
72	1.31 ^{gh} (.02)	1.28 ^e (.01)	1.24 ^{de} (.02)	1.14 ^d (.01)	0.94 ^d (.02)	1.21 ^d (.01)
73	1.23 ^e (.01)	1.23 ^d (.01)	1.24 ^d (.01)	1.32 ^{fg} (.01)	1.48 ^k (.02)	1.28 ^f (.01)
74	1.31 ^h (.01)	1.52 ^l (.01)	1.73 ^l (.01)	1.50 ^m (.01)	1.05 ^f (.02)	1.42 ⁱ (.01)
75	1.38 ⁱ (.01)	1.52 ^l (.01)	1.65 ^{jk} (.01)	1.49 ^{lm} (.01)	1.15 ^g (.02)	1.45 ^{ij} (.01)
76	1.29 ^f (.01)	1.38 ^h (.01)	1.46 ^h (.01)	1.44 ^j (.01)	1.40 ^j (.02)	1.38 ^h (.01)
77	1.43 ^j (.01)	1.35 ^g (.01)	1.28 ^{ef} (.01)	1.35 ^{gh} (.01)	1.49 ^k (.02)	1.38 ^h (.01)
78	1.14 ^d (.01)	1.21 ^d (.01)	1.28 ^f (.01)	1.30 ^f (.01)	1.34 ⁱ (.02)	1.24 ^e (.01)
79	1.40 ⁱ (.01)	1.34 ^f (.01)	1.28 ^f (.01)	1.33 ^g (.01)	1.41 ^j (.02)	1.35 ^g (.01)
80	1.33 ^h (.01)	1.48 ^k (.01)	1.62 ^j (.01)	1.62 ^o (.01)	1.60 ^l (.02)	1.50 ^l (.01)
81	1.44 ^j (.01)	1.45 ^{ij} (.01)	1.46 ^h (.01)	1.54 ⁿ (.01)	1.70 ^m (.02)	1.50 ^l (.01)
82	1.59 ^k (.01)	1.47 ^{jk} (.01)	1.34 ^g (.01)	1.36 ^{hi} (.01)	1.41 ^j (.02)	1.46 ^j (.01)
83	1.45 ^j (.01)	1.44 ⁱ (.01)	1.44 ^h (.01)	1.50 ^m (.01)	1.64 ^l (.02)	1.48 ^k (.01)
84	1.60 ^k (.01)	1.57 ^m (.01)	1.54 ⁱ (.01)	1.60 ^o (.01)	1.72 ^m (.02)	1.60 ⁿ (.01)
85	1.58 ^k (.01)	1.62 ⁿ (.01)	1.67 ^k (.01)	1.68 ^p (.01)	1.70 ^m (.02)	1.64 ^o (.01)
86	1.59 ^k (.01)	1.64 ⁿ (.01)	1.69 ^k (.01)	1.47 ^{kl} (.01)	1.03 ^e (.02)	1.52 ^m (.01)

TABLE 9, Continued. LEAST SQUARES MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS DURING TEST PERIOD BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, AND BREED

	0-56d ^a	0-112d	56-112d	56-140d	112-140d	0-140d
SEASON OF YEAR						
S ^b	1.47 ^m (.007)	1.49 ^p (.005)	1.50 ⁿ (.007)	1.49 ^r (.006)	1.46 ^o (.011)	1.48 ^q (.005)
W	1.33 ^l (.006)	1.37 ^o (.004)	1.41 ^m (.006)	1.37 ^q (.004)	1.28 ⁿ (.009)	1.35 ^p (.004)
TEST LOCATION						
B ^b	1.43 ^o (.005)	1.46 ^r (.003)	1.50 ^p (.005)	1.45 ^t (.004)	1.36 ^q (.007)	1.44 ^s (.003)
P	1.46 ^p (.010)	1.49 ^s (.007)	1.53 ^q (.010)	1.46 ^t (.008)	1.32 ^p (.015)	1.46 ^t (.006)
Y	1.32 ⁿ (.010)	1.33 ^q (.008)	1.33 ^o (.011)	1.37 ^s (.008)	1.44 ^t (.016)	1.35 ^r (.007)
BREED						
AN ^b	1.36 ^r (.007)	1.38 ^u (.005)	1.40 ^r (.007)	1.38 ^u (.006)	1.31 ^s (.011)	1.37 ^v (.005)
CH	1.51 ^t (.012)	1.54 ^w (.008)	1.56 ^t (.012)	1.56 ^x (.009)	1.57 ^v (.018)	1.54 ^x (.007)
GV	1.46 ^s (.015)	1.46 ^v (.011)	1.45 ^s (.015)	1.41 ^v (.012)	1.32 st (.024)	1.43 ^w (.010)
HH	1.29 ^q (.010)	1.34 ^t (.007)	1.39 ^r (.010)	1.36 ^u (.008)	1.30 ^s (.016)	1.33 ^u (.006)
LM	1.37 ^r (.015)	1.38 ^u (.010)	1.39 ^r (.015)	1.38 ^{uv} (.012)	1.36 ^t (.022)	1.38 ^v (.009)
HP	1.28 ^q (.012)	1.33 ^t (.008)	1.39 ^r (.012)	1.36 ^u (.009)	1.29 ^s (.018)	1.33 ^u (.007)
SM	1.55 ^u (.006)	1.57 ^x (.004)	1.59 ^u (.006)	1.53 ^w (.005)	1.42 ^u (.009)	1.54 ^x (.004)

^a0-56d = 0-56 d ADG (kg/d), 0-112d = 0-112 d ADG (kg/d), 56-112d = 56-112 d ADG (kg/d), 56-140d = 56-140 d ADG (kg/d), 112-140d = 112-140 d ADG (kg/d), 0-140d = Overall 140 d ADG (kg/d).

^bS = Summer, W = Winter; B = Beloit, Kansas, P = Potwin, Kansas, Y = Yates Center, Kansas; AN = Angus, CH = Charolais, GV = Gelbvieh, HH = Hereford, LM = Limousin, HP = Polled Hereford, SM = Simmental.

d, e, ..., w, x = means within effects (Birth Year, Season of Year, Test Location, Breed) in the same column bearing a common superscript are not different ($P > .05$).

TABLE 10. PARTIAL REGRESSION COEFFICIENTS OF AVERAGE DAILY GAINS ON STARTING AGE, FRAME SCORE, AND FRAME SCORE²

	0-56d ^a	0-112d	56-112d	56-140d	112-140d	0-140d
Starting Age ^b	.0018** (.0001) ^e	.0008** (.0001)	-.0001 (.0001)	-.0002 (.0001)	-.0003 (.0002)	.0006** (.0001)
Frame Score ^c	.2754** (.0142)	.1988** (.0102)	.1209** (.0149)	.1161** (.0118)	.1110** (.0234)	.1803** (.0090)
Frame Score ^{2d}	-.0141** (.0013)	-.0092** (.0001)	-.0041** (.0014)	-.0040** (.0011)	-.0043* (.0021)	-.0081** (.0008)

^a0-56d = 0-56d ADG, 0-112d = 0-112d ADG, 56-112d = 56-112d ADG, 56-140d = 56-140d ADG, 112-140d = 112-140d ADG, 0-140d = Overall 140d ADG.

^b(kg/d)/d.

^ckg/score unit.

^dkg/[score unit]².

^eStandard error for partial regression coefficient estimate.

*P < .05.

**P < .01.

TABLE 11. LEAST SQUARES MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS DURING TEST PERIOD BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED

	0-56d ^a	0-112d	56-112d	56-140d	112-140d	0-140d
Number	(6859)	(6857)	(6855)	(6850)	(6852)	(6854)
CHAROLAIS						
50% ^b	1.52 ^d (.17)	1.55 ^d (.12)	1.58 ^d (.17)	1.66 ^d (.14)	1.83 ^d (.27)	1.61 ^{de} (.11)
75%	1.81 ^d (.17)	1.84 ^e (.12)	1.88 ^d (.17)	1.78 ^d (.14)	1.59 ^d (.27)	1.79 ^e (.11)
88%	1.68 ^d (.30)	1.50 ^d (.21)	1.33 ^d (.30)	1.36 ^d (.24)	1.44 ^d (.47)	1.49 ^d (.19)
100%	1.53 ^d (.01)	1.56 ^d (.01)	1.59 ^d (.01)	1.58 ^d (.01)	1.55 ^d (.02)	1.56 ^d (.01)
HORN	1.62 ^e (.10)	1.59 ^f (.07)	1.56 ^e (.10)	1.57 ^e (.08)	1.60 ^e (.15)	1.59 ^f (.06)
POLL	1.64 ^e (.10)	1.64 ^g (.07)	1.63 ^f (.10)	1.62 ^f (.08)	1.60 ^e (.16)	1.63 ^g (.06)
GELBVIEH						
50% ^b	1.52 ^g (.03)	1.52 ^h (.02)	1.52 ^g (.03)	1.45 ^g (.03)	1.30 ^f (.05)	1.47 ⁱ (.02)
75%	1.57 ^g (.03)	1.53 ^h (.02)	1.50 ^g (.03)	1.46 ^g (.02)	1.39 ^f (.05)	1.50 ⁱ (.02)
88%	1.51 ^{fg} (.03)	1.49 ^h (.02)	1.47 ^g (.03)	1.41 ^g (.02)	1.30 ^f (.05)	1.45 ^h (.02)
100%	1.48 ^f (.03)	1.49 ^h (.02)	1.49 ^g (.03)	1.44 ^g (.02)	1.34 ^f (.05)	1.46 ^{hi} (.02)
HORN	1.51 ^h (.02)	1.51 ⁱ (.01)	1.51 ^h (.02)	1.44 ^h (.02)	1.29 ^g (.03)	1.47 ^j (.01)
POLL	1.53 ^h (.03)	1.50 ⁱ (.02)	1.48 ^h (.03)	1.44 ^h (.02)	1.37 ^g (.05)	1.48 ^j (.02)

TABLE 11, Continued. LEAST SQUARES MEANS AND STANDARD ERRORS OF AVERAGE DAILY GAINS DURING TEST PERIOD BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED

	0-56d ^a	0-112d	56-112d	56-140d	112-140d	0-140d
LIMOUSIN						
50% ^b	1.38 ⁱ (.04)	1.40 ^j (.03)	1.42 ⁱ (.04)	1.43 ⁱ (.03)	1.45 ^h (.07)	1.41 ^k (.03)
75%	1.39 ⁱ (.03)	1.42 ^j (.02)	1.45 ⁱ (.03)	1.41 ⁱ (.02)	1.35 ^h (.04)	1.41 ^k (.02)
88%	1.36 ⁱ (.03)	1.39 ^j (.02)	1.42 ⁱ (.03)	1.38 ⁱ (.02)	1.30 ^h (.04)	1.37 ^k (.02)
100%	1.37 ⁱ (.03)	1.38 ^j (.02)	1.40 ⁱ (.03)	1.38 ⁱ (.03)	1.34 ^h (.05)	1.38 ^k (.02)
HORN	1.40 ^j (.02)	1.41 ^k (.01)	1.42 ^j (.02)	1.40 ^j (.01)	1.37 ⁱ (.03)	1.40 ^l (.01)
POLL	1.35 ^j (.03)	1.39 ^k (.02)	1.43 ^j (.04)	1.40 ^j (.03)	1.35 ⁱ (.05)	1.38 ^l (.02)
SIMMENTAL						
50% ^b	1.57 ^{kl} (.01)	1.56 ^l (.01)	1.56 ^k (.01)	1.51 ^k (.01)	1.40 ^{jk} (.02)	1.53 ^m (.01)
75%	1.58 ^l (.01)	1.59 ^{mn} (.01)	1.60 ^l (.01)	1.54 ^l (.01)	1.40 ^j (.01)	1.55 ⁿ (.01)
88%	1.58 ^l (.01)	1.60 ⁿ (.01)	1.63 ^m (.01)	1.56 ^m (.01)	1.42 ^k (.02)	1.57 ⁿ (.01)
100%	1.55 ^k (.01)	1.58 ^{lm} (.01)	1.62 ^{lm} (.01)	1.56 ^m (.01)	1.45 ^k (.02)	1.55 ⁿ (.01)
HORN	1.57 ^m (.01)	1.59 ^o (.01)	1.60 ⁿ (.01)	1.54 ⁿ (.01)	1.43 ^l (.01)	1.56 ^o (.01)
POLL	1.56 ^m (.01)	1.58 ^o (.01)	1.60 ⁿ (.01)	1.54 ⁿ (.01)	1.41 ^l (.02)	1.55 ^o (.01)

^a0-56d = 0-56 d ADG (kg/d), 0-112d = 0-112 d ADG (kg/d), 56-112d = 56-112 d ADG (kg/d), 56-140d = 56-140 d ADG (kg/d), 112-140d = 112-140 d ADG (kg/d), 0-140d = Overall 140 d ADG (kg/d).

^b50% = Half Blood, 75% = 3/4 Blood, 88% = 7/8 Blood, 100% = Purebred; HORN = Horned, POLL = Polled.

d,e,...,n,o = means within percentage of breed and polled character (HORN, POLL) within a breed in the same column bearing a common superscript are not different ($P > .05$).

TABLE 12. LEAST SQUARES MEANS AND STANDARD ERRORS OF WEIGHT PER DAY OF AGE BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, AND BREED

	WDA1 ^a	WDA2	WDA3	WDA4	WDA5
Number	(9398)	(9763)	(9761)	(9763)	(9762)
BIRTH YEAR					
73	1.26 ^{ef} (.010)	1.23 ^j (.006)	1.28 ^h (.006)	1.30 ^{ij} (.005)	1.32 ^g (.005)
74	1.28 ^{fg} (.007)	1.21 ⁱ (.005)	1.28 ^h (.005)	1.37 ^l (.005)	1.35 ⁱ (.004)
75	1.24 ^d (.007)	1.17 ^f (.005)	1.24 ^{fg} (.005)	1.32 ^k (.004)	1.32 ^g (.004)
76	1.23 ^d (.006)	1.18 ^g (.005)	1.22 ^e (.005)	1.26 ^g (.004)	1.28 ^e (.004)
77	1.24 ^{de} (.007)	1.18 ^g (.005)	1.24 ^f (.005)	1.25 ^{ef} (.004)	1.24 ^e (.004)
78	1.28 ^g (.006)	1.23 ^j (.005)	1.24 ^f (.004)	1.26 ^{fg} (.004)	1.27 ^{de} (.004)
79	1.27 ^f (.006)	1.19 ^{gh} (.005)	1.23 ^f (.004)	1.25 ^e (.004)	1.26 ^d (.004)
80	1.28 ^g (.006)	1.20 ^h (.004)	1.22 ^e (.004)	1.29 ⁱ (.004)	1.31 ^g (.004)
81	1.30 ^h (.006)	1.17 ^f (.005)	1.22 ^e (.004)	1.26 ^g (.004)	1.29 ^f (.004)
82	1.29 ^g (.005)	1.17 ^f (.004)	1.25 ^g (.004)	1.26 ^g (.003)	1.27 ^e (.003)
83	1.27 ^f (.005)	1.13 ^d (.004)	1.19 ^d (.004)	1.23 ^d (.003)	1.26 ^d (.003)
84	1.27 ^f (.005)	1.16 ^e (.004)	1.23 ^f (.004)	1.28 ^h (.003)	1.31 ^g (.003)
85	1.26 ^e (.007)	1.19 ^h (.005)	1.26 ^g (.005)	1.31 ^k (.005)	1.34 ^h (.004)
86	1.29 ^{gh} (.007)	1.18 ^{fg} (.005)	1.24 ^f (.005)	1.30 ^j (.004)	1.28 ^e (.004)
SEASON OF YEAR					
S ^b	1.23 ⁱ (.004)	1.18 ^k (.003)	1.24 ^j (.003)	1.29 ^m (.002)	1.31 ^k (.002)
W	1.30 ^j (.003)	1.19 ^l (.002)	1.23 ⁱ (.002)	1.27 ^l (.002)	1.28 ^j (.002)

TABLE 12, Continued. LEAST SQUARES MEANS AND STANDARD ERRORS OF WEIGHT PER DAY OF AGE BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, AND BREED

	WDA1 ^a	WDA2	WDA3	WDA4	WDA5
TEST LOCATION					
B ^b	1.28 ^l (.003)	1.16 ^m (.002)	1.22 ^k (.002)	1.27 ^o (.002)	1.29 ^m (.002)
P	1.25 ^k (.005)	1.21 ^o (.004)	1.27 ^l (.004)	1.32 ^p (.003)	1.33 ⁿ (.003)
Y	1.27 ^k (.005)	1.18 ⁿ (.004)	1.22 ^k (.004)	1.24 ⁿ (.003)	1.27 ^l (.003)
BREED					
AN ^b	1.28 ^o (.004)	1.21 ^r (.003)	1.26 ^p (.003)	1.30 ^u (.003)	1.31 ^q (.003)
CH	1.28 ^o (.006)	1.20 ^q (.005)	1.24 ^o (.004)	1.29 st (.004)	1.31 ^q (.004)
GV	1.28 ^o (.007)	1.19 ^q (.006)	1.24 ^o (.005)	1.28 ^s (.005)	1.29 ^p (.005)
HH	1.29 ^o (.006)	1.22 ^r (.005)	1.26 ^p (.004)	1.30 ^u (.004)	1.31 ^q (.004)
LM	1.25 ⁿ (.007)	1.14 ^p (.006)	1.19 ^m (.005)	1.23 ^q (.005)	1.24 ^o (.005)
HP	1.25 ⁿ (.006)	1.19 ^q (.005)	1.25 ^o (.005)	1.30 ^{tu} (.004)	1.31 ^q (.004)
SM	1.23 ^m (.003)	1.15 ^p (.002)	1.21 ⁿ (.002)	1.27 ^r (.002)	1.28 ^p (.002)

^aWDA1 = Pre-weaning Weight Per Day of Age (kg/d), WDA2 = On-Test Weight Per Day of Age (kg/d), WDA3 = 56-day Weight Per Day of Age (kg/d), WDA4 = 112-day Weight Per Day of Age (kg/d), WDA5 = 140-day Weight Per Day of Age (kg/d).

^bS = Summer, W = Winter; B = Beloit, Kansas, P = Potwin, Kansas, Y = Yates Center, Kansas; AN = Angus, CH = Charolais, GV = Gelbvieh, HH = Hereford, LM = Limousin, HP = Polled Hereford, SM = Simmental.

d, e, ..., t, u = means within effects (Birth Year, Season of Year, Test Location, Breed) in the same column bearing a common superscript are not different ($P > .05$).

TABLE 13. PARTIAL REGRESSION COEFFICIENTS OF WEIGHT PER DAY OF AGE ON FRAME SCORE AND FRAME SCORE²

	PRE-WEANING WDA	ON-TEST WDA	56-d WDA	112-d WDA	140-d WDA
Frame Score ^a	.047** .0075 ^c	.037** .0056	.079** .0051	.087** .0047	.088** .0045
Frame Score ^{2b}	.006** .0007	.006** .0005	.002** .0005	.001** .0004	.001* .0004

^a(kg/d)/score unit.

^b(kg/d)/[score unit]².

^cStandard error for partial regression coefficient estimate.

*P < .05.

**P < .01.

TABLE 14. LEAST SQUARES MEANS AND STANDARD ERRORS OF WEIGHT PER DAY OF AGE BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED

	WDA1 ^a	WDA2	WDA3	WDA4	WDA5
Number	(6100)	(6286)	(6284)	(6286)	(6286)
CHAROLAIS					
50% ^b	1.29 ^d (.084)	1.12 ^d (.066)	1.21 ^d (.060)	1.28 ^d (.054)	1.33 ^d (.053)
75%	1.27 ^d (.084)	1.18 ^d (.066)	1.29 ^d (.060)	1.38 ^d (.054)	1.40 ^d (.053)
88%	1.43 ^d (.144)	1.27 ^d (.114)	1.35 ^d (.103)	1.36 ^d (.094)	1.37 ^d (.091)
100%	1.35 ^d (.007)	1.26 ^d (.006)	1.31 ^d (.005)	1.36 ^d (.005)	1.38 ^d (.004)
HORN	1.34 ^e (.047)	1.22 ^e (.037)	1.30 ^f (.033)	1.35 ^e (.030)	1.38 ^e (.029)
POLL	1.33 ^e (.048)	1.20 ^e (.038)	1.28 ^e (.035)	1.34 ^e (.031)	1.36 ^e (.030)
GELBVIIEH					
50% ^b	1.34 ^f (.016)	1.28 ^g (.013)	1.34 ^h (.011)	1.39 ⁱ (.010)	1.39 ^g (.010)
75%	1.36 ^f (.015)	1.27 ^g (.012)	1.35 ^h (.011)	1.38 ^{hi} (.010)	1.38 ^g (.009)
88%	1.35 ^f (.015)	1.26 ^g (.012)	1.32 ^h (.011)	1.35 ^{gh} (.010)	1.35 ^f (.010)
100%	1.34 ^f (.016)	1.23 ^f (.012)	1.29 ^g (.011)	1.33 ^{fg} (.010)	1.34 ^f (.010)
HORN	1.32 ^g (.009)	1.24 ^h (.007)	1.30 ⁱ (.007)	1.35 ^j (.006)	1.35 ^h (.006)
POLL	1.37 ^h (.015)	1.28 ⁱ (.012)	1.35 ^j (.011)	1.38 ^k (.010)	1.38 ⁱ (.009)

TABLE 14, Continued. LEAST SQUARES MEANS AND STANDARD ERRORS OF WEIGHT PER DAY OF AGE BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED

	WDA1 ^a	WDA2	WDA3	WDA4	WDA5
LIMOUSIN					
50% ^b	1.37 ^j (.035)	1.26 ^k (.024)	1.32 ^m (.022)	1.34 ^m (.020)	1.35 ^k (.019)
75%	1.34 ^j (.015)	1.22 ^k (.011)	1.27 ^l (.010)	1.31 ^m (.009)	1.32 ^k (.009)
88%	1.33 ^j (.015)	1.22 ^k (.011)	1.27 ^l (.010)	1.30 ^m (.009)	1.31 ^k (.009)
100%	1.27 ⁱ (.018)	1.18 ^j (.014)	1.24 ^k (.012)	1.28 ^l (.011)	1.29 ^j (.011)
HORN	1.31 ^k (.012)	1.22 ^l (.009)	1.28 ⁿ (.008)	1.31 ⁿ (.007)	1.32 ^l (.007)
POLL	1.34 ^k (.020)	1.22 ⁱ (.015)	1.27 ⁿ (.014)	1.31 ⁿ (.013)	1.31 ^l (.012)
SIMMENTAL					
50% ^b	1.30 ^l (.007)	1.23 ^o (.006)	1.31 ^q (.005)	1.36 ^q (.005)	1.37 ^o (.004)
75%	1.31 ^m (.004)	1.24 ^o (.003)	1.31 ^q (.003)	1.36 ^q (.003)	1.37 ^{om} (.003)
88%	1.29 ^l (.005)	1.21 ⁿ (.004)	1.28 ^p (.003)	1.34 ^p (.003)	1.35 ⁿ (.003)
100%	1.28 ^l (.005)	1.20 ^m (.004)	1.26 ^o (.004)	1.32 ^o (.003)	1.33 ^m (.003)
HORN	1.29 ⁿ (.003)	1.21 ^p (.003)	1.28 ^r (.002)	1.34 ^r (.002)	1.35 ^p (.002)
POLL	1.30 ⁿ (.005)	1.23 ^q (.004)	1.30 ^s (.004)	1.35 ^s (.003)	1.36 ^q (.003)

^aWDA1 = Pre-weaning Weight Per Day of Age (kg/d), WDA2 = On-Test Weight Per Day of Age (kg/d), WDA3 = 56-d Weight Per Day of Age (kg/d), WDA4 = 112-d Weight Per Day of Age (kg/d), WDA5 = 140-d Weight Per Day of Age (kg/d).

^b50% = Halfblood, 75% = 3/4 Blood, 88% = 7/8 Blood, 100% = Purebred; HORN = Horned, POLL = Polled.

d, e, ..., r, s = means within percentage of breed and polled character (HORN, POLL) within a breed in the same column bearing a common superscript are not different ($P > .05$).

TABLE 15. LEAST SQUARES MEANS AND STANDARD ERRORS OF OTHER PERFORMANCE TRAITS BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, AND BREED

	AYW ^a	REA	BF	SC	FR	PR
Number	(9543)	(8128)	(9321)	(4174)	(9763)	(5565)
BIRTH YEAR						
70	434.37 ^e (7.44)					472.63 ^{de} (66.12)
71	440.43 ^{ef} (4.64)					537.15 ^e (40.91)
72	417.68 ^d (5.81)					657.33 ^f (34.80)
73	436.12 ^e (3.00)	86.52 ^l (.61)	.70 ^m (.01)		3.36 ^d (.03)	719.45 ^f (33.19)
74	443.60 ^f (1.79)	80.81 ^j (.40)	.71 ^m (.01)	31.71 ^d (.36)	3.54 ^e (.03)	350.01 ^d (27.21)
75	444.72 ^f (1.82)	79.27 ⁱ (.38)	.70 ^m (.01)	32.10 ^d (.24)	3.98 ^f (.03)	527.61 ^e (28.75)
76	446.91 ^{fg} (1.88)	78.27 ^h (.37)	.66 ^l (.01)	33.25 ^e (.16)	4.52 ^h (.03)	554.05 ^e (29.65)
77	447.30 ^g (1.95)	74.66 ^e (.39)	.59 ^j (.01)	33.86 ^f (.17)	4.71 ⁱ (.03)	878.65 ^g (31.01)
78	432.12 ^e (1.79)	75.57 ^{ef} (.37)	.53 ^g (.01)	34.99 ⁱ (.20)	4.24 ^g (.03)	1336.07 ^k (28.01)
79	451.18 ^g (1.74)	75.73 ^f (.34)	.62 ^k (.01)	34.16 ^{fg} (.19)	4.87 ^j (.03)	1142.51 ^j (27.62)
80	479.84 ^k (1.70)	82.45 ^k (.33)	.53 ^g (.01)	34.42 ^g (.15)	5.16 ^k (.03)	1121.93 ^j (27.18)
81	474.63 ^j (1.72)	79.13 ^{hi} (.34)	.57 ⁱ (.01)	34.94 ⁱ (.14)	5.16 ^k (.03)	1078.48 ^{ij} (26.99)
82	469.09 ⁱ (1.49)	76.03 ^f (.29)	.55 ^h (.01)	34.88 ^{hi} (.13)	5.21 ^k (.02)	1111.69 ^j (23.97)
83	463.64 ^h (1.50)	73.21 ^d (.29)	.52 ^{fg} (.01)	35.06 ⁱ (.13)	5.18 ^k (.03)	1044.89 ⁱ (25.61)
84	491.37 ^l (1.54)	78.20 ^g (.34)	.50 ^f (.01)	35.95 ^j (.14)	5.46 ^l (.03)	1029.02 ^{hi} (25.43)
85	515.54 ⁿ (2.02)		.48 ^e (.01)	34.20 ^g (.20)	5.98 ⁿ (.03)	999.35 ^h (27.91)
86	496.29 ^m (2.00)		.44 ^d (.01)	34.64 ^{gh} (.18)	5.87 ^m (.03)	1267.41 ^{lk} (32.47)

TABLE 15, Continued. LEAST SQUARES MEANS AND STANDARD ERRORS OF OTHER PERFORMANCE TRAITS BY BIRTH YEAR, SEASON OF YEAR, TEST LOCATION, AND BREED

	AYW ^a	REA	BF	SC	FR	PR
SEASON OF YEAR						
S ^b	461.53 ^P (1.23)	77.56 ^m (.24)	0.58 ⁿ (.005)	34.37 ^l (.11)	4.77 ^o (.02)	815.97 ^l (16.99)
W	454.34 ^o (1.01)	79.09 ⁿ (.18)	0.58 ⁿ (.004)	33.97 ^k (.08)	4.84 ^p (.01)	928.52 ^m (12.83)
TEST LOCATION						
B ^b	456.62 ^r (.88)	78.05 ^o (.16)	0.56 ^o (.003)	34.41 ⁿ (.08)	4.82 ^q (.01)	1037.02 ^p (10.91)
P	469.02 ^s (1.56)	78.67 ^p (.32)	0.59 ^p (.006)	33.79 ^m (.13)	4.77 ^q (.02)	729.73 ⁿ (22.54)
Y	448.15 ^q (1.62)	78.24 ^{op} (.30)	0.60 ^p (.006)	34.30 ⁿ (.14)	4.82 ^q (.02)	850.00 ^o (23.57)
BREED						
AN ^b	440.31 ^u (1.24)	75.78 ^s (.26)	0.76 ^t (.005)	35.24 ^r (.12)	4.13 ^t (.02)	857.70 ^s (16.92)
CH	493.47 ^x (1.92)	83.60 ^v (.41)	0.42 ^q (.008)	33.68 ^p (.18)	5.71 ^w (.03)	870.96 ^s (26.80)
GV	470.85 ^w (2.29)	78.50 ^t (.55)	0.45 ^r (.009)	34.98 ^r (.19)	5.18 ^v (.04)	1065.96 ^t (35.82)
HH	438.88 ^u (1.72)	74.07 ^q (.36)	0.73 ^s (.008)	34.40 ^q (.19)	4.01 ^s (.03)	758.93 ^r (24.34)
LM	446.70 ^v (2.30)	82.07 ^u (.45)	0.45 ^r (.009)	31.86 ^o (.20)	4.99 ^u (.04)	851.12 ^s (34.58)
HP	425.45 ^t (1.79)	74.95 ^r (.38)	0.79 ^u (.008)	34.01 ^{pq} (.18)	3.77 ^r (.03)	682.23 ^q (26.03)
SM	489.85 ^x (.97)	79.29 ^t (.17)	0.45 ^r (.004)	35.00 ^r (.07)	5.83 ^x (.01)	1000.83 ^t (12.68)

^aAYW = Adjusted Yearling Weight (kg), REA = Ribeye Area (cm²), BF = Backfat Thickness (cm), SC = Scrotal Circumference (cm), FR = Frame Score, PR = Price (\$).

^bS = Summer, W = Winter; B = Beloit, Kansas, P = Potwin, Kansas, Y = Yates Center, Kansas; AN = Angus, CH = Charolais, GV = Gelbvieh, HH = Hereford, LM = Limousin, HP = Polled Hereford, SM = Simmental.

d, e, . . . , w, x = means within effects (Birth Year, Season of Year, Test Location, Breed) in the same column bearing a common superscript are not different (P > .05).

TABLE 16. PARTIAL REGRESSION COEFFICIENTS OF ADJUSTED YEARLING WEIGHT, RIBEYE AREA, BACKFAT THICKNESS, AND SCROTAL CIRCUMFERENCE ON STARTING AGE, 0-140D ADG, ADJUSTED YEARLING WEIGHT, AND FRAME SCORE

	AYW ^a	REA	BF	SC
Starting Age	-.0180 ^b (.0150) ^c	.057** ^d .0039	.001** ^e .0001	.026** ^e .0018
0-140d ADG		2.627** .5933	.058** .0120	.494 .2986
Adjusted Yearling Weight		.058** .0032	.001** .0001	.015** .0014
Frame Score	31.2022** (1.8032)	-.304* .1544	-.030** .0031	.291** .0687

^aAYW = Adjusted Yearling Weight, REA = Ribeye Area, BF = Backfat Thickness, SC = Scrotal Circumference.

^bkg/d and kg/score unit are units of partial regression coefficients for adjusted yearling weight (AYW) on starting age and frame score.

^cStandard error for partial regression coefficient estimate.

^dcm²/d, cm²/(kg/d), cm²/kg, and cm²/score unit are units of partial regression coefficients for ribeye area (REA) on starting age, 0-140d ADG, adjusted yearling weight, and frame score.

^ecm/d, cm/(kg/d), cm/kg, and cm/score unit are units of partial regression coefficients for backfat thickness (BF) and scrotal circumference (SC) on starting age, 0-140d ADG, adjusted yearling weight, and frame score.

*P < .05.

**P < .01.

TABLE 17. LEAST SQUARES MEANS AND STANDARD ERRORS OF OTHER PERFORMANCE TRAITS BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED

	AYW ^a	REA	BF	SC	FR	PR
Number	(6217)	(5131)	(6067)	(2831)	(6286)	(3579)
CHAROLAIS						
50% ^b	420.85 ^d (24.86)		.44 ^d (.076)	31.22 ^d (2.47)	5.29 ^d (.42)	1096.43 ^d (463.64)
75%	521.70 ^e (24.86)		.45 ^d (.076)	34.81 ^d (1.75)	6.30 ^d (.42)	2609.43 ^e (329.64)
88%	485.47 ^{de} (42.78)	72.70 ^d (8.05)	.22 ^d (.132)		5.50 ^d (.73)	346.29 ^d (463.22)
100%	496.58 ^e (2.22)	84.30 ^d (.47)	.43 ^d (.007)	34.10 ^d (.19)	5.73 ^d (.03)	932.99 ^d (30.16)
HORN	477.25 ^f (13.88)	79.52 ^f (4.03)	.36 ^e (.042)	33.16 ^e (1.01)	5.60 ^e (.24)	1095.91 ^f (183.75)
POLL	485.05 ^g (14.38)	77.48 ^e (4.10)	.41 ^f (.044)	33.59 ^e (1.06)	5.81 ^f (.24)	1396.66 ^g (192.00)
GELBVIEH						
50% ^b	475.39 ^h (4.80)	79.22 ^g (1.10)	.48 ^h (.015)	35.46 ^g (.40)	5.03 ^g (.08)	790.22 ^h (65.73)
75%	483.45 ^h (4.57)	81.05 ^g (1.21)	.46 ^h (.014)	35.57 ^g (.35)	5.26 ^h (.07)	1253.62 ⁱ (64.29)
88%	477.84 ^h (4.57)	81.33 ^g (1.04)	.41 ^g (.014)	35.43 ^g (.38)	5.32 ^h (.08)	1299.61 ⁱ (68.49)
100%	476.59 ^h (4.68)	79.51 ^g (1.32)	.40 ^g (.014)	34.16 ^f (.41)	5.37 ^h (.08)	1619.29 ^j (75.42)
HORN	474.42 ⁱ (2.86)	79.05 ^h (.69)	.42 ⁱ (.009)	35.39 ^h (.24)	5.31 ⁱ (.04)	1126.48 ^k (42.16)
POLL	482.22 ⁱ (4.49)	81.51 ⁱ (1.10)	.45 ⁱ (.014)	34.93 ^h (.35)	5.18 ⁱ (.07)	1354.89 ^l (62.97)

TABLE 17, Continued. LEAST SQUARES MEANS AND STANDARD ERRORS OF OTHER PERFORMANCE TRAITS BY PERCENTAGE OF BREED AND BY POLLED CHARACTER WITHIN BREED

	AYW ^a	REA	BF	SC	FR	PR
LIMOUSIN						
50% ^b	443.25 ^j (9.71)	83.75 ^j (2.00)	0.51 ^j (.031)	33.66 ⁱ (1.10)	4.58 ^j (.15)	662.62 ^m (88.47)
75%	454.93 ^j (4.34)	83.78 ^j (.84)	0.47 ^j (.013)	33.12 ⁱ (.36)	5.06 ^k (.07)	807.22 ^{mn} (60.64)
88%	454.55 ^j (4.36)	84.70 ^j (.87)	0.45 ^j (.013)	31.63 ⁱ (.39)	5.08 ^k (.07)	941.70 ⁿ (67.83)
100%	446.05 ^j (5.25)	83.99 ^j (1.11)	0.45 ^j (.016)	32.10 ⁱ (.45)	5.08 ^k (.09)	1164.07 ^o (83.00)
HORN	448.36 ^k (3.37)	82.74 ^k (.68)	0.43 ^k (.010)	32.36 ^j (.34)	4.92 ^l (.05)	848.90 ^p (38.86)
POLL	451.03 ^k (5.73)	85.37 ^l (1.18)	0.51 ^l (.018)	32.90 ^j (.52)	4.98 ^l (.10)	938.91 ^p (79.34)
SIMMENTAL						
50% ^b	476.38 ^l (2.07)	80.29 ^m (.42)	0.50 ^p (.007)	35.79 ^m (.20)	5.43 ^m (.03)	796.92 ^q (27.86)
75%	494.02 ^m (1.56)	80.15 ^m (.26)	0.45 ^o (.004)	35.63 ^m (.11)	5.76 ⁿ (.02)	959.90 ^r (20.08)
88%	495.66 ^m (1.69)	80.27 ^m (.30)	0.43 ⁿ (.005)	35.34 ^l (.12)	5.91 ^o (.02)	1030.10 ^s (21.87)
100%	499.41 ⁿ (1.78)	80.42 ^m (.34)	0.41 ^m (.005)	34.97 ^k (.13)	6.06 ^p (.03)	1244.13 ^t (24.34)
HORN	489.81 ^o (1.22)	80.25 ⁿ (.21)	0.44 ^q (.003)	35.50 ⁿ (.09)	5.80 ^q (.02)	968.78 ^u (14.96)
POLL	492.93 ^p (1.67)	80.32 ⁿ (.31)	0.46 ^r (.005)	35.37 ⁿ (.12)	5.78 ^q (.02)	1046.74 ^v (21.79)

^aAYW = Adjusted Yearling Weight (kg), REA = Ribeye Area (cm²), BF = Backfat Thickness (cm), SC = Scrotal Circumference (cm), FR = Frame Score, PR = Price (\$).

^b50% = Halfblood, 75% = 3/4 Blood, 88% = 7/8 Blood, 100% = Purebred; HORN = Horned, POLL = Polled.

d, e, . . . , u, v = means within percentage of breed and polled character (HORN, POLL) within a breed in the same column bearing a common superscript are not different (P > .05).

SUMMARY

Effects of year, season of year, test location, breed, and age of dam were revealed by the least squares analyses of 7 breeds. Birth weights increased in a linear fashion (.487 kg/yr) from 1975 to 1981. Average annual increases of 3.37 kg, 3.03 kg, and 2.26 kg for actual weaning weight, adjusted weaning weight, and on-test weight, respectively coupled with an annual decrease of .59 d in weaning age clearly illustrate the industry's move toward heavier bulls at earlier ages. Spring born bulls were significantly heavier and older at all pre-test weights. Breed effects were significant on all weight traits with Angus and Polled Hereford bulls lightest, followed by Hereford, Limousin, and Gelbvieh bulls with Charolais and Simmental heaviest. Age of dam had a significant effect on most pre-test weight traits with largest differences for 2-yr-old dams. Year of test had a significant effect on average daily gains across the entire test period. Season effects showed that bulls on summer tests significantly outgained bulls on winter test. Breed differences were highly significant for gains in all test periods ranging from 1.29 to 1.59 kg/d. All weight per day of age values were significantly affected by year, although trendless over the test period. Effects of season were significant for all gain periods with bulls on

winter test significantly heavier prior to test and significantly lighter over the test period. Breed differences were highly significant across all gain periods with Hereford bulls gaining fastest across all periods. Horned Charolais and polled Simmental bulls had heavier weight per day of age across the entire test period, while polled Gelbvieh bulls tended to gain faster. Differences between Limousin bulls were not significant. Adjusted yearling weights increased significantly from 1972 until 1977, then decreased significantly in 1978 and increased again in 1979 and 1980. Weights dropped again from 1980 until 1983 when a marked increase occurred to 1985 when weights averaged 515.54 kg. Season of year also had a significant effect on yearling weight with winter tested bulls heavier. Breed effects were significant with Polled Hereford bulls lightest followed by Angus and Hereford. Charolais and Simmental bulls were heaviest with Limousin and Gelbvieh intermediate. Ribeye area decreased significantly from 1973 until 1979 when an increase of 6.72 cm^2 was reported. Significant decreases occurred again from 1980 until 1983 when another significant increase was reported. Backfat thickness was reduced by .26 cm over the 13 yr period, a result of continued selection for leaner cattle. Scrotal circumference significantly increased from 1974 until 1984

when a decrease of 1.75 cm was reported. Frame score showed a near linear annual increase of .18 frame score units from 1973 until 1986. Price trends tended to follow market prices, increasing from 1970 until 1974. Another increasing trend began in 1975 and ended in 1978 with the highest average sales prices recorded. Prices were similar from 1979 to 1982 when slight decreases began which ended with significantly lower prices in 1985. Season of test had a significant influence on ribeye area, scrotal circumference, frame score, and sales price. Bulls on winter test had significantly larger ribeye areas (1.53 cm^2), larger frame scores (.07 score units), lower adjusted yearling weights (7.19 kg), and were sold at higher prices (\$112.55) than bulls on summer test. Scrotal circumference was significantly larger (.40 cm) on summer tested bulls while backfat thickness was the same over both test seasons. Breed effects were significant for ribeye area, backfat thickness, scrotal circumference, frame score, and sales price. Polled Hereford, Hereford, and Angus bulls had the smallest ribeye areas and frame scores, and greatest backfat estimates. Charolais and Limousin bulls had the largest ribeye areas, smallest scrotal circumferences, and intermediate frame scores. Angus, Gelbvieh, and Simmental bulls had the largest scrotal circumferences. Simmental and Gelbvieh bulls had

intermediate ribeye areas, and backfat estimates with the largest frame scores. Sales price was significantly affected by breed. Polled Hereford and Hereford bulls averaged significantly less than any other breed, \$682.23 and \$758.93, respectively. Gelbvieh and Simmental bulls were sold for the highest prices averaging \$1065.96 and \$1000.83, respectively while Limousin, Angus, and Charolais were intermediate. Percentage of breed and polled character within breed had significant effects only on sales price. Price of bulls generally increased with percentage. Polled character within breed had a significant effect on the price of all bulls. Significantly higher prices were paid for polled Charolais, Gelbvieh, and Simmental bulls. Polled Limousin bulls were also sold at higher prices, however the difference was not significant.

Linear regressions of pre-test performance traits on on-test age were highly significant. For each additional day of age older, bulls were lighter at birth, had heavier actual weaning and on-test weights, lighter adjusted weights and smaller weaning weight ratios. All average daily gain, adjusted yearling weight, and weight per day of age regressions, except 140-d weight per day of age regressions on frame score, were highly significant. Linear regressions of ribeye area, backfat thickness, and

scrotal circumference on on-test age and adjusted yearling weight were also highly significant. Regressions of ribeye area and backfat thickness on 140-d average daily gain, and backfat thickness and scrotal circumference on frame score were also highly significant while ribeye area on frame score was only marginally significant. Scrotal circumference regressed on 140-d average daily gain was not significant.

Rank correlation analyses were conducted on 112 and 140-d average daily gains to determine the change in rank between the two times. The results indicated that 112-d ADG provided only 80% of the information available when selecting on the basis of 140-d ADG. These results indicated that a decrease in length of test from 140 to 112 d substantially reduced the potential selection improvement for gain over the longer period. Reduction in central bull test length from 140 d to 112 d cannot therefore be recommended.

LITERATURE CITED

- Baker, J.H., J.R. Kropp, E.J. Turman and D.S. Buchanan. 1982. A comparison of different breeds for growth rates, performance traits and scrotal circumference in young beef bulls. Agric. Exp. Sta. Rep. No. 112 OK State Univ. pp. 15-18.
- Baker, J.H., J.R. Kropp, E.J. Turman and D.S. Buchanan. 1982. Growth rates and relationships among frame size, performance traits and scrotal circumference in young beef bulls. Agric. Exp. Sta. Rep. No. 112 OK State Univ. pp. 24-30.
- Baker, J.H., J.R. Kropp, E.J. Turman and R.L. Hintz. 1982. Growth rates of hip height, scrotal circumference and weight for purebred Hereford and Angus bulls. Agric. Exp. Sta. Rep. No. 112 OK State Univ. pp. 19-23.
- Baker, R.L. and A.H. Carter. 1976. The value of on-farm performance selection of Angus and Hereford bulls. Proc. of the New Zealand Soc. of Anim. Prod. 36:216.
- Baker, R.L., B.W. Wickham and C.A. Morris. 1984. Relationship between central performance test for growth in Hereford bulls and growth and carcass traits of progeny. Anim. Prod. 39:371.
- Beef Improvement Federation. 1986. Guidelines for Uniform Beef Improvement Programs. Fifth Ed. NC State Univ., Raleigh.
- Brinks, J.S., R.T. Clark, N.M. Kieffer and J.R. Quesenberry. 1962. Genetic and environmental factors affecting performance traits of Hereford bulls. J. Anim. Sci. 21:777.
- Brown, A.H., C.J. Brown and Zelpha Johnson. 1979. Relationships among postweaning body measurements and feedlot performance of bulls. AR Agric. Exp. Sta. Rep. No. 269.
- Brown, A.H., James D. Simpson and C.J. Brown. 1986. The second ten years: an analysis of Arkansas cooperative beef bull tests, 1972 through 1981. AR Agric. Exp. Sta. Rep. No. 889.

- Brown, A.H., James D. Simpson and C.J. Brown. 1986. Sources of variation influencing height at hips of bulls on performance test. AR Agric. Exp. Sta. Rep. No. 890.
- Brown, A.H., James D. Simpson and C.J. Brown. 1986. Trends in performance traits of bulls Arkansas cooperative beef bull test, 1962 through 1982. AR Agric. Exp. Sta. Rep. No. 894.
- Brown, A.H., Jr., Z.B. Johnson, J.J. Chewning and C.J. Brown. 1988. Relationships among absolute growth rate, relative growth rate and feed conversion during postweaning feedlot performance tests. J. Anim. Sci. 66:2524.
- Brown, C.J. 1965. Some factors affecting gain of beef bulls. J. Anim. Sci. Abstr. Vol. 24, p. 287.
- Brown, C.J., J.E. Brown and W.T. Butts. 1973. Evaluating relationships among immature measures of size, shape and performance of beef bulls II. The relationships between immature measures of size, shape and feedlot traits in young beef bulls. J. Anim. Sci. 36:1021.
- Brown, C.J. and Larry Keaton. 1974. An analysis of Arkansas cooperative beef bull tests, 1962 to 1972. AR Agric. Exp. Sta. Rep. No. 794.
- Brown, C.J., Carl Lueker, Curtis Melton, W.T. Wallace, Cecil Bittle, Robert Parham, R.S. Honea and M.L. Ray. 1967. An analysis of 4 years of cooperative beef bull testing at central testing stations in AR. J. Anim. Sci. Abstr. Vol. 26, p. 201.
- Brown, J.E., C.J. Brown and W.T. Butts. 1973. Evaluating relationships among immature measures of size, shape and performance of beef bulls I. Principal components as measures of size and shape in young Hereford and Angus bulls. J. Anim. Sci. 36:1010.
- Brown, J.E., C.J. Brown and W.T. Butts. 1973. Evaluating relationships among immature measures of size, shape and performance of beef bulls III. The relationships between postweaning test performance and size and shape at twelve months. J. Anim. Sci. 37:11.

- Buchanan, D.S. and C.A. McPeake. 1986. A comparison of 140 day vs shorter test periods for evaluating average daily gain in beef bulls at central test stations. Agric. Exp. Sta. Rep. No. 118 OK State Univ. pp. 14-16.
- Cain, M.F. and L.L. Wilson. 1983. Factors influencing individual bull performance in central test stations. J. Anim. Sci. 57:1059.
- Carter, R.C. and C.M. Kincaid. 1959. Estimates of genetic and phenotypic parameters in beef cattle III. Genetic and phenotypic correlations among economic characters. J. Anim. Sci. 18:331.
- Comerford, J.W., L.L. Benyshek, J.K. Bertrand and M.H. Johnson. 1988. Evaluation of performance characteristics in a diallel among Simmental, Limousin, Polled Hereford and Brahman beef cattle I. Growth, hip height and pelvic size. J. Anim. Sci. 66:293.
- Comerford, J.W., L.L. Benyshek, J.K. Bertrand and M.H. Johnson. 1988. Evaluation of performance characteristics in a diallel among Simmental, Limousin, Polled Hereford and Brahman beef cattle II. Carcass traits. J. Anim. Sci. 66:306.
- Crawford, Ben H., B.M. Jones, Jr., L.V. Cundiff and N.W. Bradley. 1967. Correlations among performance traits in individually-fed bulls. J. Anim. Sci. Abstr. Vol. 26, p. 202.
- Crouch, John and Doyle Wilson. 1989. Fall 1989 American Angus Association Sire Evaluation Report. American Angus Assoc., St. Joseph, MO. pp. 7.
- Crow, G.H., M. Donetz and S. Amal. 1988. Regressions of progeny proofs for calving ease and growth on test station performance of Charolais and Hereford beef bulls. Can. J. Anim. Sci. 68:107.
- Dalton, D.C. 1976. An analysis of Angus central bull performance tests in New Zealand. Proc. of the New Zealand Soc. of Anim. Prod. 36:210.
- Dearborn, Delwyn and C.A. Dinkel. 1959. Evaluation of final weight in the selection of performance tested bulls. J. Anim. Sci. Abstr. Vol. 18, pp. 1464-1465.

- DeNise, R.S. Kersey and D.E. Ray. 1987. Postweaning weights and gains of cattle raised under range and gain test environments. *J. Anim. Sci.* 64:969.
- DeNise, S. K., M. Torabi, D.E. Ray and R. Rice. 1988. Genetic parameter estimates for preweaning traits of beef cattle in a stressful environment. *J. Anim. Sci.* 68:1899.
- deRose, E.P., J.W. Wilton and L.R. Schaeffer. 1988. Accounting for pretest environment and selection in estimating breeding values for station-tested beef bulls. *J. Anim. Sci.* 66:635.
- deRose, E.P., J.W. Wilton and L.R. Schaeffer. 1988. Estimation of variance components for traits measured on station-tested beef bulls. *J. Anim. Sci.* 66:626.
- Dinkel, C.A. 1958. Effect of length of feeding period on heritability of post-weaning gain of beef cattle. *J. Anim. Sci. Abstr.* Vol. 17, p. 1141.
- Gacula, Maximo and C.J. Brown. 1963. Heritability of feedlot performance of beef bulls. *J. Anim. Sci. Abstr.* Vol. 22, p. 238.
- Gregory, Keith E. 1965. Symposium on performance testing in beef cattle evaluating postweaning performance in beef cattle. *J. Anim. Sci.* 24:248.
- Grizzle, J.E. and C.M. Kincaid. 1954. The relationship between body weight, daily gain, and efficiency of feed utilization in beef cattle. *J. Anim. Sci. Abstr.* Vol. 13, p. 958.
- Guilbert, H.R. and P.W. Gregory. 1944. Feed utilization tests with cattle. *J. Anim. Sci.* 3:143.
- Henningsson, Thore. 1986. Genotype-environment interaction in the performance testing of beef bulls and estimation of the genetic trend for growth rate. *Acta agriculturae scandinavica.* 36(1), pp. 41-48.
- Henningsson, Thore. 1986. Studies on performance testing for growth rate of dual purpose bulls I. General introduction and effects of breed and non-genetic factors. *Acta agriculturae scandinavica.* 36(1), pp. 3-17.

Henningssson, Thore. 1986. Studies on performance testing for growth rate of dual purpose bulls II. Genetic parameters and optimum size of the contemporary groups. *Acta agriculturae scandinavica*. 36(1), pp. 18-29.

Henningssson, Thore. 1986. Studies on performance testing for growth rate of dual purpose bulls III. Investigation of adjustment factors and inclusion of extrapolated records for daily gain. *Acta agriculturae scandinavica*. 36(1), pp. 30-40.

Henningssson, Thore. 1986. Studies on performance testing for growth rate of dual purpose bulls IV. Application of the Best Linear Unbiased Prediction (BLUP) method for evaluation of growth rate and estimation of the genetic trend. *Acta agriculturae scandinavica*. 36(1), pp. 49-59.

Johnson, Mark. 1986. Relationships among traits measured in a beef performance testing program and their effect on sales price. M.S. Thesis, Oklahoma State University.

Kennedy, B.W. and C.R. Henderson. 1975. Components of variance of growth traits among Hereford and Aberdeen Angus calves. *Can. J. Anim. Sci.* 55:493.

Kennedy, B.W. and C.R. Henderson. 1975. Genetic, environmental and phenotypic correlations between growth traits of Hereford and Aberdeen Angus calves. *Can. J. Anim. Sci.* 55:503.

Kincaid, C.M., R.C. Carter and J.S. Copernhaver. 1952. Heritability of rate of gain from progeny tests with beef cattle. *J. Anim. Sci. Abstr.* Vol. 11, p. 741.

Knapp, Bradford, Jr. and A. L. Baker. 1944. Correlation between rate and efficiency of gain in steers. *J. Anim. Sci.* 3:219.

Knapp, Bradford, Jr. and R.T. Clark. 1947. Genetic and environmental correlations between growth rates of beef cattle at different ages. *J. Anim. Sci.* 6:174.

Knapp, Bradford, Jr., and R.T. Clark. 1951. Genetic and environmental correlations between weaning scores and subsequent gains in the feed lot with record of performance steers. *J. Anim. Sci.* 10:365.

- Knapp, Bradford, Jr., and R.T. Clark. 1950. Revised estimates of heritability of economic characteristics in beef cattle. *J. Anim. Sci.* 9:582.
- Knapp, Bradford, Jr. and Arne W. Nordskog. 1946. Heritability of growth and efficiency in beef cattle. *J. Anim. Sci.* 5:62.
- Koch, Robert M. and R.T. Clark. 1955. Genetic and environmental relationships among economic characters in beef cattle. I. Correlation among paternal and maternal half-sibs. *J. Anim. Sci.* 14:775.
- Koch, Robert M. and R. T. Clark. 1955. 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, Robert K. and R.T. Clark. 1955. Influence of sex, season of birth and age of dam on economic traits in range beef cattle. *J. Anim. Sci.* 14:386.
- Koch, Robert K., Larry V. Cundiff and Keith E. Gregory. 1985. Length of feeding interval influences accuracy of selection for growth. *Agric. Res. Service ARS-42. U.S. Dept. of Agric.* p. 15.
- Koch, Robert K., K. E. Gregory, J.E. Ingalls and R.L. Arthaud. 1959. Evaluating the influence of sex on birth weight and preweaning gain in beef cattle. *J. Anim. Sci.* 18:738.
- Koch, Robert K., L.A. Swiger, Doyle Chambers and K.E. Gregory. 1963. Efficiency of feed use in beef cattle. *J. Anim. Sci.* 22:486.
- Konstantinov, K.V. and J. Vachal. 1984. Evaluation of performance-tested Bohemian Spotted bulls for growth traits by BLUP. *Scientia Agriculturae Bohemoslovaca.* 16(4) pp. 267-275.
- Koots, K.R., R.D.H. Cohen and H.H. Nicholson. 1988. Yearly trends in the performance of bulls entered at the Saskatoon ROP bull test station. *Can. J. Anim. Sci.* 68:965.

Latimer, F.G., L.L. Wilson, M.F. Cain and W.R. Stricklin. 1982. Scrotal measurements in beef bulls: heritability estimates, breed and test station effects. *J. Anim. Sci.* 54:473.

Ludwig, Craig. 1989. Hereford Sire Evaluation Report 1989. American Hereford Assoc., Kansas City, MO pp. ix-x.

McWhir, J. and J.W. Wilton. 1987. Heritabilities of predicted performance measures in beef bull tests and their relationships with feedlot efficiency measures. *J. Anim. Sci.* 64:1323.

McWhir, J. and J.W. Wilton. 1986. Prediction of traits at constant finish for performance-tested beef cattle. *J. Anim. Sci.* 63:1108.

Mangus, W.L., J.S. Brinks, J.A. Winder and A.H. Denham. 1980. The relationship of weights and measurements of performance tested bulls. *J. Anim. Sci. Abstr. Vol. 51, Supp. 1* pp. 420-421.

Marlowe, T.J., C.C. Mast and R.R. Schalles. 1965. Nongenetic influences on calf performance. *J. Anim. Sci.* 24:494.

Mavrogenis, A.P., E.U. Dillard and O.W. Robison. 1978. Genetic analysis of postweaning performance of Hereford bulls. *J. Anim. Sci.* 47:1004.

Melton, C.C., C.J. Brown, P.K. Lewis, Jr. and M.C. Hick. 1967. Beef bull performance and secondary sex characteristics. *J. Anim. Sci.* 26:244.

Nelsen, T.C., R.E. Short, J.J. Urick and W.L. Reynolds. 1986. Heritabilities and genetic correlations of growth and reproductive measurements in Hereford bulls. *J. Anim. Sci.* 63:409.

Notter, D.R. 1989. EPD's for use across breeds. Proc. from Beef Improvement Federation Res. Symp. & Annu. Meeting pp. 63-78.

O'Mary, C.C., Donald W. Vance and M.E. Ensminger. 1959. Comparison of three systems of performance testing beef cattle. *J. Anim. Sci. Abstr. Vol. 18, p.* 1465.

Patterson, R.E., T.C. Cartwright, J.H. Jones and J.J. Bayles. 1955. Performance testing of beef breeding stock. *J. Anim. Sci.* 14:1034.

Patterson, R.E., J.H. Jones, J.J. Bayles and R.V. Turnbough. 1949. Performance-testing and progeny-testing of beef breeding stock as an aid to selection. *J. Anim. Sci. Abstr.* Vol. 4, p. 608.

Patterson, T.B., G.B. Meadows and J. A. McGuire. 1982. An analysis of 26 years of beef bull performance testing at Auburn University. *AL Agric. Exp. Sta. Rep. No.* 536.

Sasaki, Y., H. Iwaisaki, T. Masuno and S. Asoh. 1982. Interaction of sire x length of testing period and estimation of genetic parameters for performance testing traits of Japanese Black bulls. *J. Anim. Sci.* 55:771.

Schaeffer, L.R., J.A. Eriksson and J.W. Wilton. 1981. Weighted averages of sire progeny tests for growth traits in record of performance beef herds. *Can. J. Anim. Sci.* 61:35.

Schalles, R.R., Josef K. Blum and Walter H. Smith. 1977. Selecting for feed conversion. *Progress Rep. No.* 291. *Agric. Exp. Sta. KS State Univ., Manhattan.* pp. 15-20.

Schalles, R.R. and T.J. Marlowe. 1967. Factors affecting test performance of beef bulls. *J. Anim. Sci.* 26:21.

Schalles, R.R. and Keith O. Zoellner. 1975. Performance of bulls on Kansas bull test. *Progress Rep. No.* 230. *Agric. Exp. Sta. KS State Univ., Manhattan.* pp. 12-13.

Schalles, R.R., K.O. Zoellner and Willard Olson. 1986. Kansas bull test 15-year summary. *Progress Rep. No.* 494. *Agric. Exp. Sta. KS State Univ., Manhattan.* pp. 73-75.

Shelby, C.E., R.T. Clark, J.R. Quesenberry and R.R. Woodward. 1960. Heritability of some economic characteristics in record of performance bulls. *J. Anim. Sci.* 19:450.

Shelby, C.E., R.T. Clark and R.R. Woodward. 1955. The heritability of some economic characteristics of beef cattle. *J. Anim. Sci.* 14:372.

- Silcox, R.E. 1980. Predicting feed efficiency of beef bulls from other measurements. M. S. Thesis, Auburn University, pp. 29-40.
- Simm, G., C. Smith and J.H.D. Prescott. 1985. Environmental effects on bull performance test results. Anim. Prod. 41:177.
- Swiger, L.A. 1961. Genetic and environmental influences on gain of beef cattle during various periods of life. J. Anim. Sci. 20:183.
- Swiger, L.A., K.E. Gregory, L.J. Sumption, B.C. Breidenstein and H.V. Arthaud. 1965. Selection indexes for efficiency of beef production. J. Anim. Sci. 24:418.
- Swiger, L.A. and L.N. Hazel. 1961. Optimum length of feeding period in selecting for gain of beef cattle. J. Anim. Sci. 20:189.
- Swiger, L.A., R.M. Koch, K.E. Gregory and V.H. Arthaud. 1961. Effect of length of the feeding period on accuracy of selection for gain and feed consumption in beef cattle. J. Anim. Sci. 20:802.
- Swiger, L.A., R.M. Koch, K.E. Gregory, V.H. Arthaud, W.W. Rowden and J.E. Ingalls. 1962. Evaluating pre-weaning growth of beef calves. J. Anim. Sci. 21:781.
- Tong, A.K.W. 1982. Effects of initial age and weight on test daily gains of station-tested bulls. Can. J. Anim. Sci. 62:671.
- Vanderwert, Wayne. 1989. 1989 Sire Summary. North American Limousin Foundation, Denver, CO. pp. 15.
- Warwick, Bruce L. and T.C. Cartwright. 1955. Heritability of rate of gain in young growing beef cattle. J. Anim. Sci. 14:363.
- Wilton, J.W., E.P. deRose and S.L. Armstrong. 1989. EPD's for group-tested bulls in Ontario. Proc. from Beef Improvement Federation Res. Symp. & Annu. Meeting pp. 48-52.
- Wilton, J. and J. McWhir. 1985. Individual and progeny measurements of growth in station and herd tests. J. Anim. Sci. 61:107.

Winters, L.M. and Harry McMahon. 1933. A proposed record of performance for beef cattle. Proc. Am. Soc. Anim. Prod. pp. 90-92.

Woldehawariat, Girma, Miguel A. Talamantes, Robert R. Petty, Jr., and T.C. Cartwright. 1977. A Summary of Genetic and Environmental Statistics for Growth and Conformation Characters of Young Beef Cattle. Second Ed. Departmental Technical Rep. No. 103 The Texas Agric. Exp. Sta. Texas A&M Univ., College Station.

FACTORS AFFECTING BULL PERFORMANCE
ON CENTRAL TESTS

by

BARBARA JEAN WARD

B.S., Purdue University, 1986

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1989

ABSTRACT OF THESIS

FACTORS AFFECTING BULL PERFORMANCE ON CENTRAL TESTS

Bull test performance data obtained from 11,494 bulls representing 32 breeds from 50 central bull tests at 3 locations over 16 yr were analyzed utilizing least squares procedures with birth year, season of year, location, breed, and percentage and polled character within breed in the model. Traits analyzed included: pre-test performance traits, average daily gains (ADG), weight per day of age (WDA), adjusted yearling weight (AYW), ribeye area (REA), backfat thickness (BF), scrotal circumference (SC), frame score (FR), and sales price. Partial regression coefficients were calculated to determine effects of on-test age, frame score, and frame score². Rank correlation analyses were conducted on 112 and 140-d ADG to determine expected amount of change in rank of bulls during the last 28 d of the test.

Birth year significantly affected all traits, however yearly trends varied. Season effects were significant on most traits with winter tested bulls having heavier starting weights, lower gains and weights. Breed effects were also significant on all traits. Angus, Hereford, and Polled Hereford bulls had the fastest gains but were lightest throughout both pre-test and test periods, with

smallest REA and frames, and greatest BF estimates. Charolais and Limousin bulls were heaviest at start of test with slowest gains, largest REA, smallest SC, and intermediate frames and prices. Simmental and Gelbvieh bulls with largest frames and highest prices were intermediate in other traits. Higher prices were paid for polled and higher percentage bulls. Linear regressions of most traits on on-test age were highly significant. Increases in REA and BF were associated with increased 140-d ADG. Large framed bulls had lower BF estimates, larger SC, and larger REA. Rank correlation analyses between 112 and 140-d ADG indicated that 112-d ADG provided only 80% of the information available when selecting on the basis of 140-d ADG.

(Key Words: Beef, Bull test, Weights, Gains, Price, Test length)