RELATIONSHIPS BETWEEN PERFORMANCE TRAITS AND INDIVIDUAL EXPECTED PROGENY DIFFERENCES IN A BEEF PERFORMANCE TESTING PROGRAM AND THEIR EFFECT ON SALES PRICE

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TABLE OF CONTENTS

LIST OF TABLES

Table | Page

CHAPTER I

INTRODUCTION

During the mid 18th century several of the British breeds of cattle were being assembled into breeds in Britain. Robert Bakewell and his followers were grouping animals similiar in type to form the British beef breeds we know today. Knowledge of Bakewell's work interested many Americans and there became a demand to export these animals to the United States. Herdbooks were established as the amount of animals in the various breeds (Shorthorn, Hereford, Angus and Devon) increased. As more breeders became involved export demand grew rapidly. Markets for purebred seedstock improved in the United States and more purebred herds were established. This was largely due to the promotion of purebred sires as a way to improve commercial stock. Many of the agricultural colleges promoted purebred sires in this way (Lush, 1945).

Rapid expansion of the purebred industry was realized up to the 1920's when an economic depression shifted the purebred industry from expansion to improvement of existing animals. Efforts to increase the number of superior animals within a breed were implemented rather than concentrating on increasing total breed numbers. The various breed associations at this time developed goals and objectives for their breed to work toward. These efforts were all geared toward improvement of purebred animals to maintain a level of genetic superiority above the commercial level (Lush, 1945).

The first organizations developed solely to record performance information on beef cattle were reported in the 1940's. In 1941 the first recorded central bull test was formed in Texas. Formation of the first state Beef Cattle Improvement Association (BCIA) occurred in Virginia in 1955. Performance Registry International (PRI) was also formed in 1955 and became one of the foremost organizations in the industry for performance information (Willham, 1982).

In the 1950's breed associations became involved in performance programs as more exotic breeds were imported. Breeds, such as Charolais, promoted themselves based on their lean growth performance. The next twenty years saw the role of performance testing shift to the breed associations, rather than the statewide associations and PRI (Middleton, 1991). To standardize the methods by which performance data were collected, the Beef Improvement Federation (BIF) was formed in 1968 (BIF, 1986). During the early 1970's breed associations began to use progeny testing programs as a basis to develop National Sire Evaluation (NSE). These procedures were taken from similiar practices used in the dairy industry. NSE programs began to use field data collected from producers as an additional tool to develop sire evaluations in the early 1980's. Development of expected progeny differences (EPD) allowed breeders a new selection tool and a distinction between within-herd breeding values and NSE. (Middleton, 1991)

The mid-1980's saw a shift from NSE evaluation methods to National Cattle Evaluation (NCE). This was a major breakthrough for the cattle industry, as EPDs could now be compared across herds for breeding females and young animals without progeny. Across herd EPDs have since became a major selection tool allowing breeders to create specialized selection programs. (Middleton, 1991).

An increased emphasis on growth and leanness in cattle since the importation of the exotic breeds in the early 1970's has changed the makeup of beef cattle in the United States. Continued selection towards growth and increased frame size has caused concern in various segments of the industry when considering what is desirable to the consumer, yet efficient to produce. Use of performance testing to identify genetically superior animals continues to be a valuable tool to genetic improvement of the seedstock and commercial animals. Identification of animals in performance testing schemes that emphasize production ideals rather than maximizing performance in all traits seems to be the trend the industry is shifting toward today (Kemp, 1992).

Two primary objectives were evaluated in this study. The first was to evaluate the relationships between performance traits measured in a centralized bull test and sales price, as well as the contribution these traits have to sales price. Trends and changes in performance traits over a period of years in a bull testing program will also be examined. The second major objective of this study was to examine the relationships between individual EPD and performance traits along with the selling price of that animal.

CHAPTER I I

REVIEW OF LITERATURE

Expected Progeny Differences

Historically, evaluation methods were based on phenotypic observations but they have developed to include many quantitative measures. Bakewell and many of the early animal breeders used phenotypic evaluation methods and pedigree information as a basis for selection. As interest in purebred animals grew in the middle 1800's and an increased number of animals were imported to the United States, Breed registries were formed to compile the pedigree and performance information on animals in the breed. Since the Breed registries were formed, the amount of information collected has increased and evaluation methods have developed to include pedigree and performance information (Lush, 1945).

Henderson (1963) described a procedure known as Best Linear Unbiased Prediction (BLUP) of random effects. This method allows prediction of genetic merit of an individual considering all performance information collected on that animal, as well as any performance records collected on relatives. BLUP procedures allow calculation of an expected breeding value which measures the additive genetic value of the animal (Kemp and Wilton, 1992). Several problems were associated with the early BLUP procedures. In order to be included in the evaluation bulls had to have progeny information available, therefore only older bulls were listed. Many bulls were being mated to genetically superior cows and no adjustment was made for this. Progeny records on a bull were included in evaluations, however a bull's individual record was not included. Another drawback to early evaluations was that breeding values were computed for sires, yet no genetic values were computed for females. Weaknesses among early BLUP methods brought about development of the Animal Model in the mid-1980's (Benyshek, 1988).

The animal model allowed bulls without progeny information to be included in sire summaries, adjustments for mating of bulls to superior cows, records on the individual were included in addition to progeny records, and genetic values were calculated for dams. This new model required extensive calculations with an enormous number of equations to be solved. To reduce the number of equations the Reduced Animal Model was developed. This method reduced the amount of computer memory necessary to run the model. The reduced animal model requires less computation because the equations to be solved are reduced by the number of non-parents. This method is currently used by breed associations in National Cattle Evaluation programs (Benyshek, 1988).

The breeder is interested in the value of the animal as a parent and a parent will transmit one half of its genetic value to the progeny. Realizing this the expected breeding value (EBV) is reduced by one half and is referred to as an expected progeny difference (EPD). An EPD predicts the transmitting ability of an animal as a parent. The best estimate of an animal's genetic value can be obtained using EPDs. An EPD is more useful than a direct measurement as it includes information on relatives, as well as individual information.

The amount of information available on each animal varies; therefore, the accuracy with which an EPD is calculated differs between animals. Each time EPDs are published an accuracy value is obtained and published along with the EPD. Individuals with large amounts of information will have higher accuracies than individuals with smaller amounts of information. The EPDs for animals with high accuracy values should be expected to change less as additional data are collected. The beef industry uses an accuracy value recommended by the Beef Improvement Federation. Accuracy values obtained range between 0 and 1. Producers can use accuracy values to determine the extent to which they will use an individual sire. Males usually have higher accuracy values than females due to an increased number of progeny records. Younger animals with fewer records will also have low accuracy values (Pollak, 1992).

In order to properly use and understand EPDs the concept of a base year must be understood. A group of animals whose EPDs average zero can be defined as a genetic base. Each breed association must choose a fixed time for a base or maintain a floating base. A fixed base allows older animals to maintain relatively constant EPDs over time. It results in more below average animals with positive EPDs over time. The floating base is the average breeding value of the most recent group of animals in the breed evaluation. Breeding values of older animals tend to fall over time as genetic change occurs. The breeding values will be relative to the present average breeding values. Breeds using a fixed base year will appear to have more positive EPDs than those with a floating base; therefore, it is necessary to consider the factors involved in calculation when looking at EPDs for different breeds. (Pollak, 1992).

Numerous studies have been conducted to assess the ability of EPDs to predict average progeny performance. Mahrt et al. (1990) compared performance of calves sired by Polled Hereford bulls selected for high or low yearling weight EPDs, as well as high or low maternal EPDs. Progeny of the high yearling weight bulls were heavier at birth, weaning and as yearlings. They also reported regressions of calf performance on sire EPD of 1.18 kg for birth weight, .79 kg for weaning weight, and 1.79 kg for yearling weight. Notter and Mahrt et al. (1991) recomputed regressions due to a change in data analysis for Polled Hereford data and reported regressions of 1.13 kg at birth, .55 kg at weaning and 1.14 kg as yearlings.

Notter et al. (1991) evaluated the ability of sire EPDs to predict progeny performance in a crossbreeding program. Angus, Hereford, Polled Hereford, Charolais, Limousin, Simmental, Gelbvieh, and Tarentaise bulls were mated to Hereford or Angus dams. A three-breed-cross was implemented with F_1 Angus- Hereford cross dams. Regressions of F_1 performance on sire EPD were 1.09 kg/kg, .79 kg/kg, 1.44 kg/kg, and 1.66 kg/kg, respectively, for birth weight, weaning weight, yearling weight, and 420-day weight. The regressions obtained for the three-breed-cross calves weaning weight on milk and weaning weight EPD of their maternal grandsires were .95 and .42 kg/kg. Notter and Cundiff concluded that EPDs for birth weight, weaning weight, yearling weight, and maternal measures in purebred animals could be used to predict progeny performance in crossbreeding schemes.

Nugent et al. (1991) examined the relationship between birth weight EPDs and various phenotypic measures taken of calves at birth. A positive correlation was obtained for birth weight EPD and all phenotypic measures of calf shape taken at birth. A relationship between cannon bone and head circumference and birth weight EPD remained significant after adjustments were made for gestation length and birthweight. Although a relationship between calf shape and birthweight EPD exist, the authors concluded birthweight EPD was an accurate predictor of actual birthweights and that no additional information concerning dystocia is presented by calf shape.

Wright et al. (1991) conducted a study to evaluate calf performance in one region based on EPDs collected from calf performance in a different region. EPDs based on bulls with calves in the northern U.S. were used to predict performance of these bulls' calves in the southern states and vice versa. Simmental-Angus and Simmental-Hereford cross calves were evaluated separately. Regressions were positive for birth weight, weaning weight and yearling weight for the southern Angus and Hereford percentage calves. The regression values that were obtained were as follows: (.75 and .91) for birthweight, (.55 and .71) for weaning weight, and (.33 and .71) for yearling weight for Angus and Hereford calves, respectively. Regressions for the northern calves based on performance of southern born calves were birthweight (.77 and .92), weaning weight (.54 and .81) and yearling weight (.62 and .86).

All of the above studies reflect that EPDs perform adequately in predicting calf performance relating to weight measurements.

Several studies have been conducted to evaluate effectiveness of maternal EPDs. In 1990 Mallinckrodt related total maternal EPDs, obtained from national sire summaries of Polled Hereford and Simmental, to performance records of daughters obtained from monthly weigh-suckle-weigh procedures. Differences in 205-day weights were found to be greater than predicted by the dams' maternal EPD for both breeds. A positive relationship was reported between milk yield and expected milk yield. In another study Marston et al. (1991) milked Angus and Simmental cows at three periods during lactation. Marston et al. (1991) reported that a 62 kg and 40 kg increase in 205-day production for Angus and Simmental, resulted in a 1 kg increase in calf weaning weight. Marston et al. (1991) concluded that milk EPDs can be used to predict differences in milk production and calf weaning weight.

Diaz (1992) examined milk EPDs and actual milk yield. The regression obtained for 12-hour milk production on sire milk EPD was .038. Marston et al. (1991) reported a higher value of .085. A correlation of .26 was found between milk EPD and actual milk production. Diaz (1992) and Marston et al. (1991) concluded that the milk EPD of sires does accurately predict the performance of their daughters.

Marshall et al. (1993) examined the relationship of sire milk and total maternal EPDs to the milk production of their crossbred daughters, as well as the weaning weights of the daughters' offspring. An overall mean estimated milk yield of 1,262 kg suggested that a difference in sire milk EPD resulted of 1 kg resulted in a difference of 1% in cumulative daughter milk yield. Marshall et al. (1993) reported a regression of daughters' offspring 214-day weight on sire total maternal EPD of 1.18 kg/kg. A pooled coefficient for regression of daughter 214-day milk yield on sire milk EPD was reported at 13.4 kg/kg. They concluded that, on average, sire milk and total maternal EPDs were positively related to the milk production of the crossbred daughters and the daughter's offspring weaning weight. Buchanan et al. (1995) reported that cows sired by high milk EPD Angus bulls weaned calves 41.5 pounds ($P<.01$) heavier than calves weaned from cows sired by low milk EPD bulls. Cows sired by high milk EPD Polled Hereford bulls had calves that were 35.6 pounds ($P<.01$) heavier at weaning than those of low milk EPD sired cows. Buchanan et al. (1995) concluded that milk EPDs can be used to accurately predict average differences in weaning weight.

Linear Measurements

Linear measurements have been used extensively throughout the past century by cattlemen as a supplemental measure of growth, as they are easily obtained and objective. Combining linear measurements with other growth measures in a performance testing scheme gives an overall prediction of an animals genetic merit for growth (Mangus, 1980). Linear measurements and their correlated traits will be discussed in this section.

Linear measurements are moderate to highly heritable, therefore they can be effectively utilized in a selection program. Heritability estimates for skeletal growth measurements have been extensively researched in the area of hip and wither height. The literature states that wither and hip height are highly correlated and are essentially equivalent measures of skeletal growth. A correlation of .927 was found between hip and wither height by Kidwell (1955). Similiar results were found by Weber (1957). This study reported that hip and wither height had similiar genetic regulation. A high correlation of .94 was found between height at the withers and height at the sacrum by Grabowski and Dyminick (1975).

Although wither and hip height are believed to be equal at maturity, some differences in the rate of growth to maturity have been found for these traits. Kidwell (1955) found a difference of 1.5 inches between wither and hip height in Hereford steers at 10 to 16 months of age, with hip height being greater. Guilbert and Gregory (1952) found a difference of 1.83 inches between wither and hip height of Hereford bulls ranging from 124 to 725 days of age. Brown (1958) showed a difference of 2 inches between wither and hip height for Angus and Hereford heifers, steers and bulls at 240 days of age. Differences of 1.65 and 1.75 inches were found between wither and hip height among several breeds in a study performed by Massey (1979). Measures of hip height were found to be largest in this study. All cattle were 205 days of age upon measurement.

Hip Height and Growth Rate

According to literature estimates, hip height is believed to increase in a linear manner up to one year of age. Guilbert and Gregory (1952) looked at growth rates in Hereford bulls and found this to be true. Hip height increased at a rate of .0338 inches/day from 124 to 369 days and then decreased to .0167 inches/day from 369 to 487 days of age. Similiarly, Brown et al. (1973) reported that Hereford and Angus bulls increased in hip height at rates of .043 and .039 inches/day, respectively. Johnson et al. (1988) reported that hip height daily growth, during a 140 day performance test, ranged from .084 cm/day to .094 cm/day among Hereford, Polled Herford and Angus bulls. Dori et al. (1974) reported faster growth rates regarding hip height from 180 to 270 days than from 270 to 505 days of age among Israeli-Fresian bulls. From 180 to 270 days these bulls grew at a rate of .043 inches/day, while they decreased to .026 inches/day from 270 to 505 days of age. Massey (1979), Maino et al. (1981), Healy (1979) and Baker (1981) all reported similiar results regarding hip height and growth rates among bulls. These studies concluded that hip height increases at a rate which is similiar among all beef breeds.

Numerous studies conclude that hip height has correlations with measures of weight and gain. Northcutt et al. (1993) reported genetic and phenotypic correlations of .78 and .58 between mature weight and height, respectively, for Angus cattle after adjusting for body condition score. Corresponding genetic and phenotypic correlations were .66 and .54, respectively for unadjusted data. Cundiff (1987) concluded that frame size at a given age is highly correlated with mature size. He also reported that under similiar environments larger framed cattle will grow faster than smaller framed cattle at a younger age. Similiar studies done by Fox and Black (1976) and Harpster et al. (1978) also reported that larger framed cattle gain at a faster rate than smaller framed cattle. Although most literature estimates are similiar to these results some variation does exist between different breeds. Cassady et al. (1989) reported that Simmental and Charolais cattle were larger framed than the Hereford and Angus cattle in their study, but all four breeds were increasing in frame size over the period of this 10 year study. Baker et al. (1981) reported moderate correlations (average .56) between off-test hip height and off-test weight for Angus, Brangus, Charolais, Hereford and Polled Hereford bulls.

Several studies during the same time period reported results that differed from Bakers' study. High genetic and phenotypic correlations between hip height and final weight (.81 and .72) were reported by Mangus et al. (1980). This study evaluated performance tested bulls from nine breeds. He reported genetic and phenotypic correlations of .64 and .45, respectively between daily gain on-test and hip height. Johnson et al. (1980) reported correlations between yearling hip height and average daily gain on three groups of Angus and Hereford bulls. Correlations for Angus bulls were .54, .45 and .78 , while correlations for Hereford bulls were slightly lower at .32, .35, and .41. Johnson et al. (1980) also reported correlations of .47, .41, .64 and .69, .62 and .87 between hip height and off-test weight for Angus and Hereford bulls, respectively. Nelson et al. (1986) reported positive correlations between hip height and weight at 403 and 490 days of age, as well as phenotypic correlations of .54 and .47, between hip height and preweaning average daily gain at 403 and 490 days of age, respectively.

Literature estimates indicate a general relationship between hip height and various weights and gains. As height is increased weight and gains tend to increase. The amount of influence height has on these other factors mentioned can be influenced by breed, environment, nutrition, and the type of cattle being tested. Use of these factors together can aid in predicting the performance of cattle more accurately.

Measures of Growth

In a performance testing scheme several measures of growth are evaluated to determine animals with superior growth. Selection for growth in beef cattle can allow an increase in overall output of beef per cow. Environmental and economic conditions may dictate wether or not increased growth is feasible. Growth measures are evaluated in most all production systems as they are easily measured and allow sufficient heritability to provide for rapid response.

Heritability of Growth Measures

Numerous studies have been conducted to examine the heritabilities among postweaning growth traits commonly evaluated in a performance testing program. In 1979 Eriksson reported heritability estimates of .43 and .48 for ADG for station tested Hereford and Charolais bulls. Wilton and McWhir (1985) reported a heritability estimate of .19 for Hereford bulls tested in Ontario, but later estimated a heritability of .50 in a subset of these data developed under more standardized testing procedures. MacNeil et al. (1991) reported a heritability estimate of .38 for postweaning ADG in a study involving beef bulls and steers. Fan et al. (1995) examined heritability estimates of average daily gain (ADG) in Hereford and Angus bulls. The heritability estimate of ADG for Hereford bulls in this study was .16, with a pooled estimate over both breeds of .26. A value of .43 was reported for the Angus bulls, which agrees with heritability estimates of MacNeil et al. (1984), de Rose et al. (1988a), and Van Arendonk et al. (1991).

In recent years, emphasis has been placed upon feed efficiency, and its heritability for selection purposes, in performance tested bulls. Koch et al. (1963) looked at feed efficiency in postweaning calves and reported heritabilities ranging from .14 to .82. A study by Jensen and Anderson (1984) reported a heritability of .45 for performance tested bulls. Brown et al. (1988) reported feed conversion heritability values of .14 and .13 for Angus and Hereford bulls fed over a 140-day test period. Van Arendonk et al. (1991) and Niewhof et al. (1992) reported a heritability estimate for feed conversion in growing dairy bulls of .26. The most recent study, Fan et al. (1995), looked at net feed efficiency measures in Hereford and Angus bulls. Heritability estimates of .14 and .28 were obtained for Hereford and Angus bulls, respectively, with a pooled estimate of .21. The literature suggests some variation in estimates of heritability with most estimates in the range.

Heritability estimates have also been reported for feed intake, on-test-weight, end-of-test weight and yearling weight. MacNeil et al. (1991) reported that metabolizable intake for beef bulls and steers on 168-day gain test was moderately heritable at .45. Fan et al. (1995) reported a lower heritability value for metabolizable energy intake of .31. On-test weight was reported to be lowly heritable by McWhir and Wilton (1987) at .08, while estimated heritability for yearling weight was reported to be .62 in this study. Fan et al. (1995) reported a lower value for heritability of yearling weight at .45. They also looked at heritability of 140-day test weight and reported a value of .52. Sasaki et al. (1982) reported a lower heritability of .20 for a similiar 140-day test weight; however, the authors of this article contribute genetic and environmental factors as a possibility to this lower value of heritability. MacNeil et al. (1991) tested bulls and steers for 168 days and reported a heritability value for final weight of .25, which was similiar to that of Sasaki (1982).

Correlations Between Growth Measures

In addition to heritability measurements, numerous studies have examined the relationships between many of the growth traits measured in performance tests. Jensen et al. (1991) reported a genotypic and phenotypic correlations between average daily gain (ADG) and daily energy intake of .59 and .34 for bulls tested ad libitum from 200 kg to slaughter. MacNeil et al. (1991) and Fan et al. (1995) obtained correlations between ADG and metabolizable energy intake (MEI) over a 168-day test period. Phenotypic correlations were .65 for both studies, while genetic correlations were .83 (Fan et al. 1995) and .73 (MacNeil et al. 1991).

Jensen et al. (1991) looked at correlations between ADG and feed conversion ratio (FCR) or total energy intake/total weight gain and reported a phenotypic corrrelation of -.86 and a genetic correlation of

-.91 for Holstein and Brown Swiss bulls. Similiarly, MacNeil et al. (1991) reported phenotypic and genetic correlations of -.48 and -.43 for ADG and feed conversion (MEI to gain) in a study utilizing Hereford and Angus bulls, as well as crossbred steers from Hereford dams. Brown et al. (1988) also reported negative phenotypic and genetic correlations, -.55 and -.79, between average growth rate and feed conversion. Fan et al. (1995) examined correlations between ADG and feed efficiency and reported phenotypic estimates of .65 and genotypic estimates of .58. In this study feed efficiency was considered as a ratio of ADG to MEI.

Correlations existing between intake and feed efficiency were addressed by Jensen et al. (1991). Feed conversion ratio or energy intake/total weight gain was lowly correlated (.10) phenotypically and negatively correlated genotypically (-.23) with daily energy intake. In a similiar study, MacNeil et al. (1991) found metabolizable energy intake to be lowly correlated with feed conversion or metabolizable energy intake/daily gain. Phenotypic and genotypic correlations were .33 and .31, respectively, for Angus and Hereford bulls over a 168-day gain test. Fan et al. (1995) reported phenotypic and genotypic correlations of -.14 and .12, respectively, for Hereford and Angus bulls during a similiar 168-day gain test.

Numerous correlations have also been found between on-test-weight, off-test-weight, test average daily gains, and yearling weights. McWhir et al. (1987) reported moderate phenotypic correlation (.55) between on-test-weight and yearling weight, as well as for test average daily gain and yearling weight (.60). A negative correlation (-.10) was reported between on-test-weight and average daily gain during this 140-day gain test. Yearling weight and off-test weight were highly correlated at .86. A moderate correlation of (.55) was reported between off-test-weight and average daily gain. Fan et al. (1995) estimated phenotypic and genotypic correlations between average daily gain and yearling weight over a 168-day test period with Hereford and Angus bulls. Pooled estimates were .84 and .70, respectively, for phenotypic and genotypic correlations.

Fan et al. (1995) also found correlations between yearling weight, intake, and feed efficiency. Yearling weight was moderately correlated with metabolizable energy intake both genotypically and phenotypically, at .51 and .55, respectively. They also examined correlations between yearling weight and feed efficiency. Correlations found here were (.47) genotypic and (.54) phenotypic for Hereford and Angus bulls.

Breed Effects on Growth

Among traits measured in a performance testing program mean differences exist between breeds. Chewning et al. (1990) looked at mean differences between breeds for average daily gain, feed per pound of gain, and daily feed intake. Breeds in this study of 2007 bulls, which was based on data from 1977 to 1986, included Hereford (HH), Angus (AN), Charolais (CH), Polled Hereford (HP), Santa Gertrudis (SG), Simmental (SM), Maine Anjou (MA), Brangus (BN), and Beefmaster (BM). Breeds ranking highest and lowest for average daily gain ($P<.05$) were MA and BM, respectively. Regarding feed/gain, BM bulls ranked highest, while CH bulls were reported as lowest ($P<.05$). The highest daily feed intakes were reported for SM bulls with BM bulls lowest ($P<.05$). Cassady et al. (1989) reported that breed had a significant effect ($P<.01$) on ADG, WDA, FE, and 365-day-weight for Angus, Charolais, Simmental, and Hereford bulls included in a 10 year study of 566 bulls. Cain and Wilson (1983) analyzed breed differences among 8,636 bulls and found that Simmental and Charolais bulls outperformed Angus and Hereford bulls regarding ADG, WDA, and 365-day weight. An older study, done by Schalles and Marlowe (1967), revealed that breed influenced ADG, WDA, and 365-day-weight in a performance testing data set including 997 bulls.

Scrotal Circumference Relating to Other Traits

Reproductive efficiency is one of the most important elements in a cost effective beef cattle production system. Numerous factors affect reproductive efficiency in beef cattle. To effectively select for reproductive efficiency it is critical to address the relationships between the traits involved. Scrotal circumference is a moderately heritable trait, which is correlated with many other growth and reproductive traits. Knowledge of the relationships between scrotal circumference and other traits will allow selection for increased reproductive efficiency.

Favorable correlations are shown between scrotal circumference of sire and the reproductive traits of that sires' daughters. Heritability estimates for scrotal circumference average .45 according to Martin et al. (1992). Numerous studies have reported favorable correlations between age of puberty in heifers and scrotal circumference. In 1982 Lunstra reported a correlation of (-.98) between age of puberty and scrotal circumference over an average of 8 breeds. Brinks et al. (1978) and King et al. (1983) reported genetic correlations between scrotal circumference in yearling bulls and age of puberty in half-sib heifers of (-.71) and (-1.07), respectively.

Scrotal circumference has also been correlated with other female reproductive traits. Toelle and Robison (1985) reported that testicular development was correlated favorably to pregnancy rates, age at first breeding and age at first calving. Smith et al. (1989a,b) reported regressions of -.67 in day of first calving, and -.83 in days of age at first calving of female offspring per centimeter of scrotal circumference of the sire. The above studies indicate that sire scrotal circumference could be a valuable selection tool to improve reproductive traits in female offspring.

In addition to reproductive traits, scrotal circumference is also correlated with growth. Smith et al. (1989b) reported decreases in birthweight of progeny for each additional centimeter of scrotal circumference; however, weaning weight, yearling weight, and postweaning average daily gain of progeny increased. Similiar results were reported by Makerechian et al. (1983) and Knights et al. (1984) concluding a positive relationship between testicular size of sire and postnatal growth rate of progeny.

Postweaning feed level, age, weight, and height were reported to affect scrotal circumference according to Bourdon and Brinks (1986). Scrotal circumference was affected by weight more than any other factor. Anything which caused an increase in weight also increased scrotal circumference. Heritabilities of weight-adjusted scrotal circumference and age-adjusted scrotal circumference were .46 and .49, respectively. Correlations among scrotal circumference and growth traits were found to be moderate to high. They reported a genetic correlation of .44 between yearling weight and scrotal circumference, which was the highest among growth traits.

Several studies have reported correlations between scrotal circumference and growth traits such as yearling weight. Knights et al. (1984) reported phenotypic and genotypic correlations between scrotal circumference and yearling weight of .26 and .68, respectively. Yearling weight was more strongly correlated with scrotal circumference than weaning or birth weights. Nelsen et al. (1986) reported correlations between scrotal circumference and weights taken at 403 and 490 days of age. Correlations were .44 and .61 for these Hereford bulls at 403 and 490 days. They also reported correlations of .35 and .61 between scrotal circumference and height at 403 and 490 days of age.

A correlation of .80 was reported by Lunstra et al. (1978) between body weight and scrotal circumference in young bulls. Willet and Ohms (1957) reported correlations between body weight and scrotal circumference when bulls were on a 140-day performance test. Correlations of .60 and .56 were reported for on-test-weights and off-test-weights respectively. Similiar decreases in correlations between on-test-weights, off-test-weights and scrotal circumference were reported by Coulter (1978).

Effect of Test Length on Performance

Until recently, most central bull test stations have utilized a 140-day testing period to collect performance data. Several studies have been conducted to look at the effects of a 140-day testing period versus 112-day testing periods. Test periods were shortened to lessen overall costs associated with testing, decrease excessive fatness and reduce soundness problems that were occuring. The original 140-day testing periods were based on data collected from cattle in the early 1950's and 1960's. Current Beef Improvement Federation recommendations recommend a minimum of 112 day test period for centralized performance tests (BIF, 1990). Drastic changes in cattle types since the 1950's also brought about reason to reevaluate the length of testing periods.

To effectively evaluate differences in test length it is necessary to examine growth rates during test periods, as well as efficiency measures. Kemp (1990) reported that bulls ranked similarly for average growth rate when tested for 112 versus 140 days. Similiarly, Hoff and Brinks (1977) reported a correlation of .93 between 112-day average growth rate and 140-day average growth rate. Schaeffer (1978) reported a correlation of .95 between average growth rate during 112-day and 140-day test length for Limousin bulls. McPeake and Buchanan (1986) also reported a high correlation of .91 for average growth rates over the same periods. Franklin et al. (1987) reported a correlation of .92 between 112-day weight gain and 140-day weight gain.

Brown et al. (1991) looked at various measures of gain and efficiency over 112 and 140-day testing periods. Average daily gains were higher from 1 to 84 days than from 84 to 112 days or 112 to 140 days. Gains from 84 to 112 days were also higher than those reported from 112 to 140 days. This might suggest that the animals evaluated were reaching the inflection point of their growth curve at some point prior to 112 days. Measures of feed intake were equal from 84 to 112 days and 112 to 140 days. Equal measures of intake between these periods, yet decreasing average daily gain from 112 to 140 days might indicate these animals are depositing more fat late in the test period than early in the test period. According to this study, less feed is required per kg of gain from 1 to 84 days than from 84 to 112 or 112 to 140 days during the test. Feed required per kg of gain was also less from 84 to 112 days than from 112 to 140 days. This is supported by numerous studies indicating that as cattle fatten the efficiency of feed utilization will decrease (Gregory et al., 1962; Hedrick, 1972; Dikeman, 1973).

Results reported here indicate that a 112-day testing period is an effective way to evaluate performance measures in a central bull testing scheme, which will allow reduction in costs of testing and declines in lameness problems associated with longer test periods. High correlations between growth rates of 112 and 140 days tests indicate that we can obtain much of the same information from the shorter test period. Estimates of efficiency indicate shortening of the test period should increase feed efficiency, which will subsequently decrease testing costs to producers.

Pretest Environmental Influences on Growth Performance

Evaluation of bulls under a uniform testing environment is the primary goal of central bull testing stations; however, environmental influences occurring prior to test may affect growth performance. Several studies have looked at correlations between pretest gains and gains on test. Tong (1982) reported negative environmental correlations, between pretest and test gains, ranging from -0.22 to -0.52. Similiarly, de Rose et al. (1988a) reported a correlation -.19 between average daily gain to weaning and test average daily gain.

Selection of animals based on preweaning performance may also alter performance on test. de Rose et al. (1988b) reported that for 66% of herd-years, the mean average daily gain to weaning of tested calves was higher than for untested contemporaries. Preweaning average daily gains were higher for tested bull calves than untested contemporaries during 34% of all herd-years from 1970 to 1985. This study indicates selection of animals with superior preweaning growth traits as individuals to be tested. Negative correlations between pretest average daily gains and average daily gains on-test seem to favor animals from poorer pretest environments.

Collins-Lusweti and Curran (1985) reported that herd of origin effects accounted for .50 and .18 of the total variance regarding on-farm and test station performance data, respectively. Their study utilized field and performance data from Charolais, Hereford, South Devon and Welsh Black cattle. Tawonezi and Khombe (1986) reported that herd of origin had highly significant ($P<.001$) effects on on-test weight, off-test weight, average daily gain and feed efficiency in Mashona bulls tested over an 11-year period. Amal and Crow (1987) looked at herd of origin effects on test performance in Angus, Hereford, Charolais and Simmental cattle. At the beginning of the test herd of origin accounted for 39% of the variation in bull weights for Angus and Hereford cattle. Among Charolais and Simmental cattle, 33% of variation in beginning weights was due to herd of origin effects. Amal and Crow (1987) reported that variation due to herd decreased to 15% for the Angus and Hereford data when they looked at 140-day cumulative gains. A similiar figure of 16% was reported for variation due to herd looking at Charolais and Simmental 140-day cumulative gains.

As reported by numerous studies, it is clear that considerable variation does exist between cattle from different environments and herds. Several suggestions have been made to lessen environmental influences. Reducing the beginning-of-test age to as low as 30 days post-calving, as suggested by Lewis and Allen (1974) might lessen herd-of-origin effects considerably. Lengthening the pretest adjustment period would lessen the amount of compensatory gains realized by lighter animals from poorer pretest environments. This should allow animals to begin testing on a more equal basis and reduce the amount variation realized on test due to pretest environment.

CHAPTER III

RELATIONSHIPS BETWEEN PERFORMANCE TRAITS AND INDIVIDUAL EXPECTED PROGENY DIFFERENCES IN A BEEF PERFORMANCE TESTING PROGRAM AND THEIR EFFECT ON SALES PRICE

Abstract

A total of 3085 bulls (A=806 Angus, B=497 Brangus, H=533 Hereford, P=601 Polled Hereford, C=399 Charolais and L=249 Limousin) completed the 140-day test from 1981 to 1986. From 1987 to 1994 performance data were collected on 4343 bulls (A=2384 Angus,B=487 Brangus, H=220 Hereford, P=544 Polled Hereford, G=132 Gelbvieh, L=360 Limousin and S=216 Simmental) completing the 112-day test. These bulls were approximately 7 to 8 months old when placed on test at Oklahoma Beef Incorporated (OBI). OBI performance data were collected on the following traits: on-test weight (OFFICWT), off-test weight (OFFWT), 365-day height (HT365), 365-day weight (WT365), cumulative average daily gain (CUMADG), cumulative weight per day of age (CUMWDA), off-test scrotal circumference (SC), and test index (INDEX).

Least squares means were calculated to determine trends in performance traits. Trends among OFFICWT showed increases for all breeds except G and S. OFFWT increased during 140-day test for all breeds, yet decreased during 112-day test for all breeds except H and P. HT365 increased over both test periods for all breeds except S and C. WT365 showed an increase for all breeds during 140-day test. Increases in WT365 during 112-day test were shown for P, H and G, while the other breeds decreased. A, P, B, and H bulls showed increases in CUMADG, while C, G and S decreased. No trends in CUMADG were evident for L bulls. CUMWDA increased for all breeds during 140-day test. P, H and G bulls showed increases in CUMWDA during 112-day test while all other breeds decreased. Slight increases were shown for SC among all breeds except G and S bulls who decreased slightly.

Performance records were combined with sales price from 2419 bulls (1202 Angus, 201 Brangus, 159 Hereford, 387 Polled Hereford, 252 Limousin, 51 Charolais, 86 Simmental and 81 Gelbvieh) sold in

OBI All-Breed Performance Tested Bull Sales from 1983 to 1994 to evaluate the effect that performance traits had on selling price. Performance traits included OFFICWT, OFFWT, HT365, WT365, CUMADG, CUMWDA, SC and INDEX. None of these traits were highly correlated with price, with the highest correlation being .53 between price and INDEX among Gelbvieh bulls. Changes in price per unit change in each trait accounted for 40 to 58% of the variation in selling price due to performance traits.

Individual expected progeny differences (EPDs) were correlated with selling price and performance traits on Angus and Polled Hereford bulls to determine their relationships. EPDs included were birthweight (BW), weaning weight (WW), yearling weight (YW) and milk (MM). Small correlations were found among EPDs and performance traits for both breeds. Correlations between EPDs and price were also low, except for BW which was -.10 for A.

Introduction

Identification of animals in performance testing schemes that emphasize production ideals rather than maximizing performance in all traits seems to be the trend the industry is shifting toward today. Use of performance testing to identify genetically superior animals continues to be a valuable tool to genetic improvement of seedstock and commercial beef cattle. Sire selection can account for eighty percent of genetic improvement in a given beef cattle herd. Thus, identification of bulls who emphasize performance ideals in performance testing schemes becomes an important tool to improvement of beef cattle herds.

One method to evaluate and compare bulls is the central bull test stations. Central bull testing schemes allow a unique environment to compare animals from different herds. Centralized bull test stations were first established in the early 1950's. Test stations allow commercial and purebred producers a means to compare bulls which have been tested under common management and environmental conditions but come from different herds.

It is necessary for producers to be able to identify relationships between performance traits and economically feasible traits. To identify animals that are suitable to a specific environment and breeding program these relationships must be identified. As buyers look at bulls in a performance testing program it also becomes useful to determine the contribution various performance traits have to sales price. Since expected progeny differences have become more widely used it also becomes important to realize their relationship to performance traits and also their contribution to selling price.

Two primary objectives were evaluated in this study. The first was to evaluate the relationships between performance traits measured in a centralized bull test and sales price, as well as the contribution these traits have to sales price. Trends and changes occurring over a period of years in a bull testing program will also be examined. The second major objective of this study was to examine the relationships between individual EPD and performance traits along with the selling price of that animal.

Materials and Methods

This study utilized performance data collected from Angus, Brangus, Hereford, Polled Hereford, Limousin, Charolais, Gelbvieh, and Simmental bulls tested at Oklahoma Beef Incorporated from 1981 to 1994. Bulls tested prior to 1987 completed a 140-day test, while those tested from 1987 to 1994 were tested for 112 days. The 28 days removed to shorten the test period were taken off the first part of the official test period. This allowed the bulls to arrive at an older age yet finish the test at approximately 365 days of age. A total of 3085 bulls (806 Angus, 497 Brangus, 533 Hereford, 601 Polled Hereford, 399 Charolais and 249 Limousin) completed the 140-day test from 1981 to 1986. From 1987 to 1994 performance data were collected on 4343 bulls (2384 Angus, 487 Brangus, 220 Hereford, 544 Polled Hereford, 132 Gelbvieh, 360 Limousin and 216 Simmental) completing the 112-day test.

The bulls arrived at the test station at approximately 8 to 9 months of age. Before the initial test began the bulls were allowed a two to three week warm up period. Table 1 shows the ration Angus, Brangus, Charolais and Limousin bulls were fed during 140-day test, while Table 2 indicates the 140-day ration Hereford and Polled Hereford bulls were fed. Table 3 shows the ration all breeds were fed from the beginning of the 112-day test until the ration changed in April 1991. Table 4 presents the updated ration fed from 1991 until present. Measures of hip height and weight were taken when the bulls began the official test. Bulls were weighed every 28 days throughout the test period. Upon completion of the test measurements of hip height, weight and scrotal circumference were taken. Scrotal circumference measurements were obtained by drawing the testicles into the scrotum and placing a self releasing metal tape around the widest diameter. Two measures of hip height were taken and the average hip height from the two is reported in the data. Performance traits included in this study were on-test weight (OFFICWT), off-test weight (OFFWT), 365-day weight (WT365), 365-day height (HT365), cumulative average daily gain (CUMADG), cumulative weight per day of age (CUMWDA), off-test scrotal circumference (SC) and test index (INDEX). Table 5 indicates how these performance traits were calculated.

Least squares means were calculated for each breed using the general linear models procedure of SAS (1985). Means generated were used to evaluate trends in performance traits over 140 and 112-day test periods. The data present for each breed were analyzed separately to account for differences due to breed. Data for 140 and 112-day test periods were also analyzed separately by breed. Contemporary groups were defined as animals within the same test group for each breed. Effects of year and contemporary group within year were included in the model, as well as the residual error term. Traits included in this analysis were OFFICWT, OFFWT, WT365, HT365, CUMADG, CUMWDA and SC.

Performance records were combined with sales price from 2419 bulls (1202 Angus, 201 Brangus, 159 Hereford, 387 Polled Hereford, 252 Limousin, 51 Charolais, 86 Simmental and 81 Gelbvieh) sold in OBI All-Breed Performance Tested Bull Sales from 1983 to 1994 to evaluate the effect that performance traits had on selling price. Performance traits that were included were OFFICWT, OFFWT, HT365, WT365, CUMADG, CUMWDA, SC and INDEX. Sale catalogs were available to buyers at the time of sale. Information in the catalog included identification of the bull, sire and dam identification, pedigree, birthdate, owner, sire expected progeny differences from 1985 to 1987, and individual expected progeny differences from 1989 to 1994. Performance data included in the catalog were: on-test weight, off-test weight, adjusted yearling height, adjusted yearling weight, ultrasound measurements of ribeye area and ribfat, scrotal circumference, average daily gain, weight per day of age, number of animals in group tested and an index of on-test performance. The index is a composite value of average daily gain, weight per day of age and adjusted yearling weight; however, it varies slightly between breeds.

Residual correlations between performance traits and selling price were generated using the manova procedure found in GLM of SAS (1985). The effects of year and contemporary group within year were included in the model. Data from 140 and 112-day test periods were combined for this analysis, yet breeds were analyzed separately. Simmental and Gelbvieh bulls contained only 112-day data, while Charolais bulls were limited 140-day data. All other breeds contained data for both testing periods. Contributions of performance traits to selling price were calculated using a backwards elimination multiple regression procedure in GLM. Effects of year and contemporary group within year were also included in this model. Analyses were repeated until only those traits that made significant contributions to selling price remained.

Individual expected progeny differences (EPDs) were correlated with performance traits and selling price on Angus and Polled Hereford bulls to determine their relationships. The EPDs represented individual estimates at the time of sale and were taken from OBI catalogs from 1989 to 1994. EPDs included were birthweight (BW), weaning weight (WW), yearling weight (YW) and milk (MM). The number of observations for Polled Hereford bulls were 142, 139, 139 and 139 for BW, WW, YW and MM, respectively. Among Angus bulls the number of observations were 537, 643, 396, and 633 for BW, WW, YW and MM, respectively. Correlations were generated separately for each particular EPD and the performance traits to allow for a larger number of observations. Sales price and EPD correlations were generated using a model which included BW, WW, YW, MM, and price. Data from 479 bulls (348 Angus and 131 Polled Hereford) were used to generate correlations between EPDs and price. The correlations were generated using the manova procedure mentioned previously accounting for differences due to year and contemporary group within year in the model. Analysis of Angus and Polled Hereford data were performed separately.

Results and Discussion

Year and contemporary group within year effects were significant sources of variation among the performance traits measured in this study. Least squares analysis of variance regarding 112-day data revealed significant effects ($P < .05$) of year on OFFICWT for Angus and Gelbvieh bulls. OFFWT was also significantly affected ($P < .05$) by year for Gelbvieh bulls. Effects of year ($P < .05$) on HT365 were shown for all breeds with the exception of Hereford, Limousin and Gelbvieh bulls. Year did not significantly effect WT365, CUMADG, CUMWDA, or SC for any of the breeds ($P > .05$). Effects of contemporary group within year on HT365, WT365, CUMWDA, and SC were significant ($P < .05$) for all breeds. OFFICWT was significant ($P < .05$) for contemporary group within year effects for all breeds except Hereford and Gelbvieh. Contemporary group within year effects on OFFWT and CUMADG were found ($P < .05$) among all breeds except Gelbvieh.

Year and contemporary group within year were significant sources of variation among most of the traits of interest for 140-day data. OFFICWT was significantly affected ($P < .05$) by year for Angus and Hereford bulls. Year effects were found among Angus, Hereford and Polled Hereford ($P < .05$) regarding OFFWT and WT365. HT365 for Angus, Brangus, Hereford and Polled Hereford bulls was significantly affected by year ($P < .05$). Year effects for CUMADG were found among Angus and Polled Hereford bulls ($P < .05$). CUMWDA of Angus, Hereford, Polled Hereford and Limousin bulls was affected by year ($P < .05$). Effects of year on scrotal circumference were nonsignificant ($P > .05$) for all breeds except Polled Hereford. Contemporary group within year effects were important sources of variation ($P < .05$) for all breeds regarding OFFICWT and OFFWT. HT365 and CUMADG were significantly affected ($P < .05$) by contemporary group within year for all breeds except Polled Hereford. All breeds except Limousin were significantly affected ($P < .05$) by contemporary group within year regarding WT365 and CUMWDA. Contemporary group within year significantly affected SC ($P < .05$) for all breeds other than Limousin and Charolais.

Least Squares Means By Breed

Table 6 gives least squares means, standard errors and number of observations for Angus bulls regarding all performance traits evaluated in this study. OFFICWT increased from 1982 to 1986 during 140-day test. Upon entering the 112-day test period in 1987, OFFICWT continued to increase until 1989, however it then decreased until 1993. An increase was shown in 1994; however, it should be noted that this estimate was based on the lowest number of observations. Trends in OFFWT were similiar to OFFICWT with increases shown from 1982 to 1986 and a gradual decline during the 112-day test. An increase was shown for WT365 during the 140-day test period; however, a decrease was shown once the bulls were started on 112-day test in 1987. A continual increase from 1982 to 1991 was shown regarding HT365, yet a decrease was realized from that point. During the 140-day test CUMADG and SC increased rapidly until 1987 when the 112-day test began. A slight increase in ADG and SC was evident for the 112-day period, other than a low point for both traits occuring in 1994. It should be noted that this low point was associated with an estimate that has the largest standard error due to a low number of observations present in that year. Increases in 140-day CUMWDA followed the same trend as ADG during the 140-day period, however during the 112-day period CUMWDA tended to decrease.

Results for least squares means, standard errors and number of observations for Brangus bulls during 140 and 112-day test periods are indicated in Table 7. The results found resemble the results for Angus bulls for all traits considered. OFFICWT and OFFWT increased throughout the 140-day period, but then decreased during the 112-day testing period. Trends for HT365 and WT365 were very similiar with both showing continual increases until 1991 and declining thereafter. Increases were shown for CUMADG and CUMWDA throughout the 140-day testing period, however CUMADG continued to increase after the 112-day period began. Trends for CUMWDA showed a decrease for the 112-day testing period. There was a slight increase shown in SC during the 140-day period; however, a decrease was shown during the 112-day test.

Least squares means, standard errors number of observations for Hereford bulls during 140 and 112-day test periods are indicated in Table 8. A continual increase in OFFICWT and HT365 was evident for Hereford bulls throughout both test periods. Trends for OFFWT and WT365 differ as the increase didn't continue through the 112-day period. The weights at the beginning of the 112-day test were similiar to those at the beginning of the 140-day test, yet an increase during the 112-day period was evident. Slight increases were evident for CUMADG and SC during both test periods. During the 140-day test CUMWDA increased; however, a decrease was shown at the beginning of the 112-day test. Increases in CUMWDA were evident from the beginning of the 112-day test until 1993.

Results of least squares means and associated values for Polled Hereford bulls during 140 and 112-day test are shown in Table 9. Unlike the breeds mentioned earlier, Polled Hereford bulls showed continual increases for all traits except SC. Trends in OFFICWT and OFFWT were very similiar for 140 and 112-day testing periods. Both traits showed a continual increase from 1981 to 1994. Increases for WT365 and HT365 were similiar during both testing periods. These traits also continued to increase over both test periods. An increase during both testing periods was evident for CUMADG and CUMWDA. From 1981 to 1986 SC increased; however, during the 112-day test it appeared to be decreasing.

Table 10 gives results of least squares means for Limousin bulls during 140 and 112-day test periods. Trends for OFFICWT and OFFWT were very similiar over both test periods. Both weights show increases from 1982 to 1986. From 1987 until 1993 both traits show a continual decrease. A continual increase in WT365 was evident during the 140-day test period; however, a decrease is shown from 1987 until 1993. Similiarly, HT365 increased during the 140-day testing periods and then began to decrease in 1989 during the 112-day test. Limousin bulls showed increases in CUMADG and CUMWDA throughout the 140-day testing period; however, during the 112-day period both traits peaked in 1989 and decreased thereafter. There was no evident change in SC from 1982 through 1986, yet SC increased to a peak in 1988 and then decreased until 1993.

Table 11 refers to results of least squares means for Charolais bulls on 140-day test from 1981 to 1986. Charolais bulls remained relatively constant regarding OFFICWT and OFFWT during this period.

A peak for both traits was shown in 1986; however, this value was associated with the largest standard error. Similiarly, HT365 seemed to remain constant from 1981 to 1986. An increase was shown for WT365 during this six year period. There was a slight decrease evident for both measures of gain, CUMADG and CUMWDA, over the 140-day test period in this study for Charolais bulls. An increase was shown in 1986 for both traits, but it should be realized that there was a large standard error associated with this estimate. It appeared that SC decreased from 1981 to 1985, although an increase was shown in 1986. Again, the estimate of SC in 1986 was associated with a large standard error.

References to least squares means for Gelbvieh bulls tested on 112-day test from 1988 to 1993 are found in Table 12. From 1988 to 1993 there was a constant decrease in OFFICWT and OFFWT. In contrast, HT365 and WT365 seemed to be increasing over this period. It was evident that CUMADG was decreasing for Gelbvieh bulls from 1988 to 1993. Although CUMADG seemed to be decreasing, CUMWDA for this period remained relatively constant. Trends for SC during this period showed a decrease for 112-day tested Gelbvieh bulls.

Table 13 refers to least squares means for Simmental bulls tested for 112 days from 1989 to 1993. Trends for OFFICWT and OFFWT tended to decrease for Simmental bulls during this five year period. A decrease was evident for HT365 and WT365 during this study , with the lowest point occuring in 1990 for both traits. A very slight decrease was shown for CUMADG from 1989 to 1993. CUMWDA decreased form 1989 to 1990; however, an increase was evident from 1990 to 1993. Measures of least squares means for SC were highest in 1989, with a decrease evident after that point.

Trends among performance traits over the period of this study were in general agreement with previous studies. Johnson et al. (1988) reported increases with regard to on-test weight, off-test weight, off-test height, average daily gain, and off-test scrotal circumference over 140-day test periods from 1981 to 1987. Cassady et al. (1989) also reported increases in frame size and scrotal circumference among Angus, Charolais, Simmental and Hereford bulls tested for 140 days from 1976 to 1985. Increases were shown for these traits during the 140-day test periods of this study; however, decreases were evident among several traits after the test period was shortened to 112 days. Northcutt et al. (1993) also reported increases for Angus bulls among on-test weight, off-test weight, on-test height and 365-day height during both 140 and 112-day test periods. These results are also in agreement with the trends found in this study.

Correlations Among Performance Traits and Sales Price

Correlations among sales price and performance traits are given in Table 14. Price was positively correlated (P<.001) with all performance traits for Angus bulls. Correlations for Angus bulls represent 140 and 112-day test periods combined. Price had low correlations to OFFICWT, HT365 and SC of .23, .26 and .17, respectively. All other traits were moderately correlated with price. Correlations for OFFWT, WT365, CUMADG, CUMWDA and INDEX were .46, .46, .41, .45 and .52, respectively. These correlations were in agreement, although somewhat lower than those found by Northcutt et al. (1993).

Among Brangus bulls correlations between price and performance traits for 140 and 112-day test periods were low to moderate. Brangus bulls had positive correlations (P<.01) between price and performance traits that were similiar to those of Angus. These correlations may be referred to in Table 14. Correlations between price and OFFICWT, HT365, CUMADG and SC were moderately low at .28, .28, .32 and .23, respectively. Moderate correlations of .44, .38, .42 and .45 were found between price and OFFWT, WT365, CUMWDA and INDEX, respectively. These correlations also agreed with those found by Northcutt et al. (1993); however, the correlation for SC was somewhat higher in this study. Johnson et al. (1988) found correlations among OFFWT, ADG and price that were in agreement with this study.

Hereford bulls tested for 140 and 112-day periods showed moderate positive correlations (P< .01) between performance traits and price, although SC and OFFICWT were lowly correlated with price. It should be noted that the correlation between OFFICWT and price was nonsignificant (P>.05). Table 14 provides a reference to correlations between performance traits and price. Correlations of .38, .44, .42, .37, .44 and .51were found among price and OFFWT, HT365, WT365, CUMADG, CUMWDA, and INDEX, respectively. The only low correlation of .23 was found among SC and price.

Correlations among price and performance traits for Polled Hereford bulls tested for both 140 and 112-day performance traits are listed in Table 14. Correlations between price and performance traits were all positive. All performance traits were moderately correlated with price except SC, which had a low correlation (P<.05) with price of .12. Correlations for OFFICWT, OFFWT, HT365, WT365, CUMADG, CUMWDA and INDEX were .32, .47, .36, .42, .34, .46 and .47, respectively (P<.001). Correlations found here also agree with those found by Johnson et al. (1988).

Limousin bulls tested for 140 and 112-day periods had positive correlations between price and all performance traits as shown in Table 14. A low correlation of .13 was found between price and SC, however this trait was nonsignificant (P>.05). Correlations between OFFICWT, CUMADG and price were lowly moderate (P<.001) at .29 and .23, respectively. OFFWT, HT365, WT365, CUMWDA and INDEX were moderately correlated (P<.001) with price revealing correlations of .42, .38, .45, .50 and .50, respectively. Correlations generated for Limousin bulls are in general agreement with those of previous studies (Johnson et al. 1988, Cassady et al. 1989 and Northcutt et al. 1993).

Correlations among price and performance traits of Charolais bulls tested for 140 days are provided in Table 14. Price was positively correlated with all traits , however OFFICWT, OFFWT, CUMADG and SC had low correlations which were nonsignificant (P>.01). Moderate correlations of .46, .43, .39 and .46 were found among price and HT365, WT365, CUMWDA and INDEX, respectively. Correlations for Charolais bulls that were significant seem to resemble those found for Hereford bulls in this study. Cassady et al. (1989) reported similiar results regarding correlations between price and HT365, WT365, CUMWDA and INDEX.

Data for Simmental bulls during 112-day test periods showed positive correlations between all traits and price with the exception of a negative correlation for CUMADG. Although CUMADG was negatively correlated with price this trait was nonsignificant (P>.10). Other nonsignificant traits included: HT365 and SC (P>.05). Lowly moderate correlations (P<.01) of .37, .36 and .35 were generated between OFFICWT, OFFWT and INDEX, respectively. Price was moderately correlated (P<.001) with

WT365 and CUMWDA at .52 and .51, respectively. Correlations for Simmental bulls agree with literature estimates; however, a lower correlation was found between INDEX and price in this study.

All performance traits were positively correlated with price among Gelbvieh bulls on 112-day test periods. These correlations can be found in Table 10. A nonsignificant correlation (P>.01) of .25 was found between OFFICWT and price. All other performance traits were significantly correlated with price (P<.01). A correlation of .33 was reported for SC and price among Gelbvieh bulls and it should be noted that this was the highest correlation found for any breed in this study. Correlations found in this breed tend to agree with the literature; yet, SC was more correlated with price in this study.

Correlations between price and performance traits were low to moderate across breeds and were in agreement with previous literature estimates. The highest correlations with regard to all breeds except Simmental were between test index and price. Cassady et al. (1989) and Northcutt et al. (1993) also reported the highest correlations between index and price. Scrotal circumference showed the lowest correlations with price over all breeds. Johnson et al. (1988), Cassady et al. (1989), and (Northcutt et al. (1993) also reported the lowest correlations between scrotal circumference and price. Low to moderate correlations were found among growth measures and price in this study. Previous performance test studies also reported similiar correlations between growth traits and price (Johnson et al., 1988; Cassady et al., 1989; Northcutt et al., 1993). Results from this study and previous work indicate buyers are interested in all growth measure with an emphasis on test index. Scrotal circumference seems to be less important to buyers than other performance traits.

Contribution of Performance Traits to Selling Price

Changes in price per unit change in each performance trait are shown in Table 15. Values for each breed are shown separately in this table. Any missing values indicate that the trait did not have a significant contribution to selling price; therefore, CUMWDA did not make a significant contribution to selling price for any of the breeds. Regression coefficients given in Table 15 indicate the amount of change in selling price that can be explained by one unit of change in the particular trait. Selling price of

Hereford, Polled Hereford and Limousin bulls was significantly affected by OFFICWT. Each kilogram of change in OFFICWT accounted for changes in selling price of $-7.10, $4.15, and $3.37 among Hereford, Polled Hereford and Limousin bulls, respectively. A kilogram of change in OFFWT increased selling price of Angus, Brangus and Hereford bulls by $2.81, $3.41 and $9.35, respectively. Final selling price of all breeds except Simmental was significantly affected by HT365. Changes of $17.27, $28.59, $65.53, $29.59, $36.38, $48.76 and $32.77 in selling price were realized per centimeter of change in HT365 for Angus, Brangus, Hereford, Polled Hereford, Charolais, Limousin and Gelbvieh bulls, respectively. Significant changes in selling price of $4.53, $3.09 and $6.61 were realized for each kilogram of change in WT365 among Angus, Polled Hereford and Simmental bulls, respectively. Large changes in prices were indicated for each kilogram of change in CUMADG among Angus, Brangus and Polled Hereford bulls. Changes in selling price due to CUMADG for the respective breeds were $1016.60, 943.04 and $1099.41. Only Hereford and Gelbvieh bulls showed contributions of SC to selling price. Each centimeter of change in SC would change selling price by $20.87 and $25.24 in Hereford and Gelbvieh bulls, respectively. Charolais, Limousin, and Gelbvieh bulls showed changes of $17.84, $63.63 and $26.45, respectively, for each unit of change in INDEX. Northcutt et al. (1993) reported that off-test weight, test index and 365-day height contributed to 56% of variation in sales price of Angus bulls. Off-test weight, off-test height and average daily gain had significant contributions to sales price in a study by Johnson et al. (1988). Regression coefficients allow us to see specific changes in price for each trait; yet, they do not explain the total variation in price explained by all traits combined.

The R^2 value indicated in the bottom row of Table 15 explains the amount of variation in price explained by those traits indicated in the table. Angus bulls were significantly affected by OFFWT, HT365, WT365 and CUMADG and these traits accounted for 52.12% of the variation in sales price. Selling price among Brangus bulls varied 58.76% due to OFFWT, HT365 and CUMADG. Variation in price of 54.49% for Hereford bulls was due to the effects of OFFICWT, OFFWT, HT365 and SC. Only 44.04% of variation in sales price for Polled Hereford bulls was explained by changes in OFFICWT, HT365, WT365 and CUMADG. The price of Charolais bulls was affected by HT365 and INDEX; yet, these two traits accounted for 45.73% of the variation in price. Limousin bulls varied by 42.82% in selling price due to changes in OFFICWT, HT365 and INDEX. A lower variation in price of 39.22% was estimated for Simmental bulls due to WT365. One of the larger R^2 values, consisting of 58.12%, was etimated for Gelbvieh bulls and was explained by HT365, SC and INDEX.

The contribution of various performance traits to sales price in this study were in agreement with previous literature. Literature estimates of R^2 values were somewhat lower for Johnson et al. (1988). Johnson et al. (1988) reported R^2 values of .3656, .3796 and .3989 for Angus, Hereford and Polled Hereford bulls, respectively. Cassady et al. (1989) reported that frame score, feed:gain ratio and test index accounted for only 29.5% of the variation in price of Angus, Charolais, Simmental and Hereford bulls tested for 140 days. Northcutt et al. (1993) reported an R^2 value of .56 for Angus bulls which was similiar to those found in this study. Height at 365 days contributed to price for all breeds in this study. This was also evident for previous studies (Johnson et al., 1988; Cassady et al., 1989; Northcutt et al., 1993).

It should be noted that several other factors may have influenced the results given here. Sale order, physical appearance of the animal, reputation of the breeder and pedigree may influence sales price. Sale order is an important consideration when looking at differences in selling price, as price can be influenced by time of sale. Sale order for the bulls in this study was based on the index of the animal; therefore the high indexing bulls sold before lower indexing bulls. Certain physical characteristics of the bull at the time of sale may influence the price. It was also impossible to determine the effect of visual appraisal on the sale price of the animal. The reputation and integrity of certain breeders and their breeding programs may have also impacted the selling price of certain bulls. Preference of certain pedigrees over others may also have had an effect on sales price.

Correlations Among Performance Traits and Individual Expected Progeny Differences

Correlations between performance traits and individual expected progeny differences (EPDs) for Angus and Polled Hereford bulls are listed in tables 16 and 17, respectively. OFFICWT was lowly correlated with all performance traits. MM was nonsignificant (>.10) with regard to OFFICWT, as well as OFFWT, CUMADG, and CUMWDA. Low correlations of .24, .19, and .22 were reported between OFFWT and BW, WW and YW, respectively. HT365 and WT365 also had low correlations with all EPDs; yet a negative correlation was reported between HT365 and MM. CUMADG was significantly correlated (P<.10) with BW and YW; however, these correlations were low. Low correlations of .20, .20 and .19 were reported between CUMWDA and BW, WW and YW, respectively. BW and WW were nonsignificant with regard to SC; however significant correlations of -.12 and .07 were reported for YW and MM, respectively. All other performance traits were lowly correlated with INDEX among Angus bulls. Few significant correlations (P<.10) were observed among performance traits and EPDs for Polled Hereford bulls. EPDs for BW, WW and YW were positively correlated with OFFICWT and HT365; yet, correlations were low. A negative correlation of -.20 was also reported between MM and HT365 for Polled Hereford bulls. BW and YW had low correlations of .19 and .20, respectively with OFFWT. Correlations between all other performance traits and EPDs were nonsignificant (P>.10).

Positive correlations between growth measures and EPDs in the literature agree with correlations found in this study. Previous literature indicates that EPDs are an accurate predictor of progeny performance (Mahrt et al., 1990; Notter et al., 1991; Wright et al., 1991; Mallinckrodt et al., 1990; Marston et al., 1991; Diaz et al., 1992; Marshall et al., 1993; Buchanan et al., 1995). BW, WW,YW, and MM were positively correlated with performance traits in this study for both breeds. The only negative correlations occurred between MM and HT365 for both breeds; however SC was negatively correlated with WW and YW in Angus bulls. Individual EPDs appear to be lowly correlated with performance; however, there is a positive association as reported in previous literature.

Correlations Among Price and Individual Expected Progeny Differences

Table 18 refers to correlations between price and EPDs for Angus and Polled Hereford bulls. All correlations were positive for Angus bulls with the exception of BW. A low negative correlation (P<.10) of -.10 was evident between BW and price. Correlations of .19, .24, and .27 were reported (P<.001) between price and WW, YW, and MM, respectively. Polled Hereford bulls showed positive correlations between all EPDs and price; however, all correlations were nonsignificant ($P>.10$). The correlation between BW and price was positive, yet very low at .02. Price was positively correlated with WW, YW and MM at .11, .12 and .09, respectively.

Positive correlations between price and growth EPDs support estimates of positive correlations found for growth traits and price in the literature. Low correlations were reported between individual EPDs and price; however, all correlations were positive except BW and price. Correlations generated indicate that buyers are interested in increased growth and maternal traits. A negative correlation between BW and price for Angus bulls indicates a preference towards lower birthweight sires. Based on this study buyers are selecting bulls with lower birthweight EPDs and increased growth and maternal EPDs.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Identification of animals in performance testing schemes that emphasize production ideals rather than maximizing performance in all traits seems to be the trend the industry is shifting toward today. Use of performance testing to identify genetically superior animals continues to be a valuable tool to genetic improvement of seedstock and commercial beef cattle. Sire selection can account for eighty percent of genetic improvement in a given beef cattle herd. Thus, identification of bulls who emphasize performance ideals in performance testing schemes becomes an important tool to improvement of beef cattle herds. Central bull testing schemes allow a unique environment to compare animals from different herds.

It is necessary for producers to be able to identify relationships between performance traits and economically feasible traits. To identify animals that are suitable to a specific environment and breeding program these relationships must be identified. Two primary objectives were evaluated in this study. The first was to evaluate the relationships between performance traits measured in a centralized bull test and sales price, as well as the contribution these traits have to sales price. Trends and changes occurring over a period of years in a bull testing program will also be examined. The second major objective of this study was to examine the relationships between individual EPD and performance traits along with the selling price of that animal.

This study utilized performance data collected from Angus, Brangus, Hereford, Polled Hereford, Limousin, Charolais, Gelbvieh, and Simmental bulls tested at Oklahoma Beef Incorporated from 1981 to 1994. Bulls tested prior to 1987 completed a 140-day test, while those tested from 1987 to 1994 were tested for 112 days. A total of 3085 bulls (806 Angus, 497 Brangus, 533 Hereford, 601 Polled Hereford, 399 Charolais and 249 Limousin) completed the 140-day test from 1981 to 1986. From 1987 to 1994 performance data was collected on 4343 bulls (2384 Angus, 487 Brangus, 220 Hereford, 544 Polled Hereford, 132 Gelbvieh, 360 Limousin and 216 Simmental) completing the 112-day test.

These bulls arrive at the test station at approximately 8 to 9 months of age. Before the initial test begins the bulls are allowed a two to three week warm up period. Measures of hip height and weight are taken when the bulls begin the official test. Bulls are weighed every 28 days throughout the test period. Upon completion of the test measurements of hip height, weight and scrotal circumference are taken. Scrotal circumference measurements are obtained by drawing the testicles into the scrotum and placing a self releasing metal tape around the widest diameter. Two measures of hip height are taken and the average hip height from the two is reported in the data. Performance traits included in this study were on-test weight (OFFICWT), off-test weight (OFFWT), 365-day weight (WT365), 365-day height (HT365), cumulative average daily gain (CUMADG), cumulative weight per day of age (CUMWDA), off-test scrotal circumference (SC) and test index (INDEX). The following individual expected progeny differences were also examined for Angus and Polled Hereford bulls: birth weight (BW), weaning weight (WW), yearling weight (YW) and maternal milk (MM).

Trends among the performance traits mentioned above were examined using the least squares means procedure found in the general linear models (GLM) method of SAS (1985). Effects of year and contemporary group within year were included in the model. Correlations between performance traits and sales price were obtained using the manova procedure found in GLM. Again, effects of year and contemporary group within year were included in the model. The contribution each performance trait had on sales price was determined using a Backwards Elimination Multiple Regression procedure in GLM with the effects of year and contemporary group within year included in the model. Individual EPDs were correlated with sales price and performance traits using the manova procedure also. Main effects of year and contemporary group within year were also included in this model. Significant effects of year and contemporary group within year were noted among most of the performance traits within each breed.

Differences did occur in trends for performance traits of the various breeds included in this study. Angus bulls showed increases for OFFICWT, OFFWT, HT365, WT365, CUMADG, CUMWDA and SC throughout the 140-day test period, but tended to decrease or maintain a constant level throughout the 112-day period. Results for Brangus bulls were very similiar to Angus, with an increase in all traits during the 140-day test years and a decrease during 112-day test years. Among Hereford bulls continual increases are evident for OFFICWT, HT365, CUMADG and SC from 1981 until 1993. Increases were evident through 140-day test periods for OFFWT, WT365 and CUMWDA, however these traits decreased to a lower level at the beginning of the 112-day period with a slight increase after that point. Increases were shown from 1981 to 1994 regarding all traits except SC, which leveled out during 112-day test years, for Polled Hereford bulls. Limousin bulls showed increases for all traits except SC from 1982 to 1986. A peak occurred near 1989 for all traits and then decreases occurred from that point until 1993. Among Charolais bulls on 140-day test all performance traits showed either a slight increase or no evident change other than WT365, which increased. Gelbvieh bulls on 112-day test showed decreases for OFFICWT, OFFWT, CUMADG and SC, with all other traits showing slight increases. Simmental bulls show decreases for all performance traits from 1989 until 1993 during 112-day test.

Most of the growth measure evaluated increased during the period of this study except for some decreases when the test period was shortened. Charolais, Gelbvieh and Simmental were the only breeds with evident decreases occurring among the majority of performance traits evaluated. The most evident increases appeared to be for weights and heights. The least amount of change occurred in SC during both test periods evaluated.

Results of phenotypic correlations between price and performance traits were in general agreement with the literature reviewed. The lowest correlations were found between SC and price. Moderate correlations were found between OFFWT, WT365, CUMWDA and INDEX. Somewhat lower correlations were indicated for OFFICWT, HT365 and CUMADG. Price was most strongly correlated with INDEX in this study. None of the traits evaluated in this study were highly correlated with price. Regression analysis revealed that performance traits explained 40 to 58% of the variation in selling price over all breeds. The largest values of price per unit change in a trait occurred for CUMADG among Angus, Brangus and Polled Herford bulls. Although it was a large contributor, this trait was lowly correlated with price.

Phenotypic correlations among EPDs and performance traits were low, as were correlations between EPDs and sales price. Low correlations were reported between WW, YW and MM and price for Angus bulls. Price was negatively correlated with BW among Angus bulls. Correlations between price and EPDs were all nonsignificant regarding Polled Hereford bulls. Performance traits were low or negatively correlated with price for Angus and Polled Hereford bulls. Low correlations found here agree with previous literature estimates regarding growth traits and price.

In conclusion, performance traits evaluated in this study display a large amount of variation due to breed, year and test group within a year. Growth traits appear to be increasing among most of the breeds in this study. A change in growth traits is also evident at the point of the change in test length. For most of the traits a peak is evident during the 112-day period, with a decrease thereafter. Some of the decrease in these traits may be contributed to selection patterns dictated by industry recommendations. Traits such as height and weight appear to be decreasing at a point where many changes occurred regarding industry ideals for frame score and slaughter endpoints.

Performance traits appear to have only a small to moderate effect on selling price of performance tested beef bulls. Off-test weight, 365-day weight, weight per day of age and index were traits with the highest correlations to selling price. Cumulative average daily gain contributed a large amount to the variation in selling price among Angus, Brangus and Polled Hereford bulls, however it had no significant effect on the other breeds. The most consistent contributor to sales price was 365-day height, as it was a factor among all breeds except Simmental. A large amount of variation exists between breeds regarding the traits which contribute to selling price. Performance traits explained from 40 to 58% of variation in selling price among the breeds in this study.

Expected progeny differences were lowly correlated with performance traits and price in this study. All EPDs were lowly correlated with price and performance measures. Birth weight EPD showed a negative correlation to price among Angus bulls. This indicates increasing selection toward lower birth weights among commercial and purebred producers. Among Polled Hereford bulls EPDs were nonsignificantly correlated with price and most of the performance traits evaluated. It appears that EPDs are not a major influence on the selling price of animals although they have become widely used among purebred breeders.

This indicates that a large array of factors other than performance traits and EPDs contribute to price. Visual appraisal at the time of sale may be a major factor affecting sales price, yet the extent is unkown. Management of bulls once they are off test until the time of sale can have an effect on condition and physical appearance of the animal. Certain physical characteristics of bulls at time of sale can influence sale price among various buyers. In addition, pedigrees, breeder and breeding programs all may play a large role in determining selling price of performance tested beef bulls.

Table 1. Ration fed to Angus, Brangus, Charolais and Limousin bulls during 140-day test

Ingredient	Percent of Ration
Cottonseed hulls	10.00
Corn	58.95
Oats	15.00
Soybean oil meal	6.50
Cottonseed meal	6.50
Salt	.30
Calcium carbonate	1.00
Dicalcium phosphate	.25
Vitamin A	+
Tylan 40G	+
Fat	2.00

Table 2. Ration fed to Hereford and Polled Hereford bulls during 140-day test

Ingredient	Percent of Ration
Corn	33.87
Oats	15.00
Cottonseed hulls	10.00
Alfalfa pellets	15.00
*Supplement pellet	24.38
Fat	1.75

*Supplement Pellet	
Soybean oil meal	46.72
Rice mill feed	47.90
Calcium carbonate	1.07
Salt	2.05
Dicalcium phosphate	2.13
Bovatec 68 gram	.09
Vitamin premix	.05

Table 3. Ration fed to Angus, Brangus, Hereford, Polled Hereford, Limousin, Simmental and Gelbvieh bulls during 112-day test prior to April 1991

Ingredient	Percent of Ration
Corn	36.20
Oats	13.00
Fat	1.80
*Supplement pellet	27.20
Dehy pellet	11.80
Cottonseed hulls	10.00

*Supplement pellet

Cottonseed meal	20.94
Soybean meal 47.5	21.74
Soybean hulls	49.94
Trace mineral & salt	1.80
Calcium carbonate	2.0
Dicalcium phosphate	3.4
Beef cattle premix	.05
Rumensin 60	.08
Tylan 40	.04

Table 4. Ration fed to Angus, Brangus, Hereford, Polled Hereford, Limousin, Simmental and Gelbvieh bulls during 112-day test from April 1991 to 1994

Ingredient	Percent of Ration
Alfalfa dehy	11.80
Cottonseed hulls	10.00
*Supplement pellet	25.71
Oats	13.00
Corn dent no. 2	37.70
Fat	1.80

* Supplement pellet	
Soybean hulls	14.02
Soymeal 47.7	10.41
Limestone 38%	.77
Salt	.46
Rumensin 60	.0244
Tylan 40	.0116
Vitamin A-30,000	.0090

Table 5. Calculation of Performance Traits

Trait	**Calculation**
On-test weight (OFFICWT)	actual weight
Off-test weight (OFFWT)	actual weight
365-day height (HT365)	average of two heights taken off-test and adjusted to 365 days < 365 days +.033 in./day > 365 days - .025 in./day
365-day weight (WT365)	highest weight per day of age (WDA) from 320-400 days of age x 365 + age of dam adjustment bulls < 320 days of age use 112-day WDA
Cumulative average daily gain (CUMADG)	$\frac{\text{Off-test weight - On-test weight}}{\text{test length}}$
Cumulative weight per day of age (CUMWDA)	$\frac{\text{Off-test weight}}{\text{actual age}}$
Off-test scrotal circumference (SC)	actual measurement off-test
Off-test index (INDEX)	composite value of CUMADG,CUM WDA and WT365

Table 6. Least squares means, standard errors and number of observations by year for performance traits[a] of Angus bulls during 140 and 112 (*)-day test periods.

	OFFICWT (KG)	OFFWT (KG)	HT365 (CM)	WT365 (KG)	CUMADG (KG)	CUMWDA (KG)	SC (CM)
1982	278.43	518.93	122.48	501.45	1.71	1.36	37.16
	±2.64	±3.30	±0.25	±3.19	±0.02	±0.01	±0.44
	216	215	215	215	216	215	214
1983	281.27	516.17	124.30	509.87	1.66	1.38	37.66
	±2.82	±3.55	±0.27	±3.43	±0.02	±0.01	±0.52
	223	222	222	222	223	222	203
1984	296.03	552.43	126.27	541.65	1.83	1.46	37.81
	±3.55	±4.43	±0.34	±4.28	±0.02	±0.01	±0.59
	150	150	150	150	150	150	149
1985	292.91	540.29	127.47	535.11	1.77	1.44	37.57
	±3.60	±4.50	±0.35	±4.34	±0.02	±0.01	±0.61
	99	99	99	99	99	99	95
1986	321.01	580.93	128.81	563.12	1.87	1.53	37.94
	±3.50	±4.37	±0.34	±4.22	±0.02	±0.01	±0.58
	118	118	118	118	118	118	118
1987*	324.31	533.45	127.55	529.16	1.86	1.43	37.65
	±3.03	±3.60	±0.33	±3.43	±0.02	±0.01	±0.48
	213	204	205	205	205	205	203
1988*	319.99	539.81	130.05	531.71	1.98	1.45	37.87
	±4.33	±5.62	±0.52	±5.37	±0.03	±0.01	±0.75
	262	256	256	256	256	256	256
1989*	336.34	556.10	131.94	545.78	1.96	1.48	37.88
	±3.14	±3.69	±0.34	±3.53	±0.02	±0.01	±0.51
	294	289	289	289	289	289	287
1990*	331.82	551.38	131.52	538.20	1.96	1.46	37.10
	±3.36	±4.01	±0.37	±3.83	±0.02	±0.01	±0.54
	339	316	316	316	316	316	314
1991*	330.10	546.28	132.57	542.26	1.97	1.46	37.95
	±4.41	±2.97	±0.27	±2.83	±0.02	±0.01	±0.40
	321	312	316	316	316	316	311
1992*	318.33	538.98	130.41	536.44	1.97	1.44	37.72
	±2.56	±3.05	±0.28	±2.87	±0.02	±0.01	±0.41
	407	391	406	406	406	406	390
1993*	312.49	533.94	130.02	531.16	1.99	1.43	38.19
	±2.50	±3.07	±0.27	±2.81	±0.02	±0.01	±0.41
	503	477	487	487	487	487	477
1994*	324.09	515.31	129.17	518.69	1.68	1.38	37.01
	±7.25	±8.87	±0.83	±8.50	±0.05	±0.02	±1.19
	44	43	42	42	42	42	42

[a] Refer to page 44 for a description of performance traits

Table 7. Least squares means, standard errors and number of observations by year for performance traits[a] of Brangus bulls during 140 and 112 (*)-day test periods.

	OFFICWT (KG)	OFFWT (KG)	HT365 (CM)	WT365 (KG)	CUMADG (KG)	CUMWDA (KG)	SC (CM)
1981	276.95	495.64	125.12	454.62	1.55	1.24	35.21
	±3.22	±4.20	±0.40	±3.94	±0.02	±0.01	±0.76
	162	161	161	161	162	161	77
1982	276.62	503.68	125.97	477.58	1.62	1.30	37.12
	±4.26	±5.56	±0.52	±5.21	±0.03	±0.01	±0.74
	113	113	113	113	113	113	112
1983	287.82	507.18	126.13	473.33	1.54	1.28	37.44
	±4.95	±6.46	±0.61	±6.05	±0.03	±0.02	±0.85
	78	78	78	78	79	78	77
1984	302.50	533.62	126.97	487.09	1.65	1.32	37.69
	±5.14	±6.69	±0.63	±6.27	±0.03	±0.02	±0.89
	64	64	64	64	64	64	61
1985	304.07	538.53	129.62	501.40	1.68	1.37	36.90
	±7.02	±9.14	±0.86	±8.56	±0.04	±0.02	±1.25
	49	50	50	50	50	50	49
1986	303.76	542.92	129.97	498.37	1.71	1.36	36.85
	±7.08	±9.23	±0.87	±8.65	±0.04	±0.02	±1.22
	29	29	29	29	29	29	29
1987*	321.33	504.15	131.06	510.56	1.59	1.36	35.19
	±6.15	±8.04	±0.81	±7.57	±0.04	±0.02	±1.23
	53	40	40	40	40	40	40
1988*	355.73	557.02	136.03	527.56	1.80	1.44	38.12
	±6.35	±7.72	±0.78	±7.26	±0.04	±0.02	±1.18
	54	54	54	54	54	54	54
1989*	340.97	549.13	136.12	518.19	1.87	1.42	38.11
	±4.99	±6.12	±0.62	±5.76	±0.03	±0.02	±0.94
	77	76	76	76	76	76	76
1990*	338.04	543.91	136.87	527.94	1.83	1.44	37.02
	±4.87	±5.98	±0.60	±5.63	±0.03	±0.02	±0.92
	77	75	75	75	75	75	75
1991*	337.36	542.32	137.55	523.97	1.83	1.42	36.95
	±4.53	±5.50	±0.56	±5.18	±0.03	±0.01	±0.84
	92	92	92	92	92	92	92
1992*	329.03	535.98	136.25	508.58	1.85	1.39	36.86
	±5.02	±6.19	±0.63	±5.82	±0.03	±0.02	±0.95
	75	74	74	74	74	74	74
1993*	314.67	517.44	131.94	485.77	1.82	1.33	36.69
	±5.46	±6.70	±0.68	±6.31	±0.03	±0.02	±1.03
	59	58	58	58	58	58	58

[a] Refer to page 44 for a description of performance traits

Table 8. Least squares means, standard errors and number of observations by year for performance traits[a] of Hereford bulls during 140 and 112 (*)-day test periods.

	OFFICWT (KG)	OFFWT (KG)	HT365 (CM)	WT365 (KG)	CUMADG (KG)	CUMWDA (KG)	SC (CM)
1981	283.43	499.06	122.76	483.98	1.53	1.30	35.62
	±2.78	±3.18	±0.23	±2.98	±0.01	±0.01	±0.46
	220	219	219	219	220	219	139
1982	302.94	533.47	124.85	510.93	1.65	1.37	36.97
	±4.69	±5.33	±0.38	±4.98	±0.02	±0.01	±0.68
	97	97	97	97	97	97	96
1983	298.46	528.74	125.82	520.23	1.63	1.39	36.10
	±4.52	±5.13	±0.37	±4.80	±0.02	±0.01	±0.64
	73	73	73	73	73	73	72
1984	317. 61	549.66	127.13	540.66	1.66	1.45	36.04
	±8.47	±9.61	±0.69	±8.99	±0.04	±0.02	±1.19
	65	65	65	65	65	65	65
1985	316.20	557.74	127.55	542.57	1.74	1.46	36.82
	±4.97	±5.64	±0.40	±5.28	±0.03	±0.01	±0.73
	57	57	57	57	57	57	54
1986	328.31	570.26	127.52	541.61	1.73	1.47	36.48
	±10.02	±11.38	±0.81	±10.64	±0.05	±0.03	±1.41
	21	21	21	21	21	21	21
1987*	316.13	506.14	126.39	499.43	1.70	1.35	36.37
	±6.39	±7.54	±0.53	±6.91	±0.03	±0.02	±0.87
	72	72	72	72	72	72	72
1988*	327.54	530.27	128.36	494.31	1.81	1.36	37.13
	±5.83	±6.92	±0.49	±6.34	±0.03	±0.02	±0.81
	57	56	56	56	56	56	55
1989*	339.41	538.54	130.69	509.58	1.77	1.40	36.96
	±8.10	±9.63	±0.68	±8.83	±0.04	±0.02	±1.12
	32	31	31	31	31	31	31
1990*	333.38	547.21	131.94	531.31	1.91	1.45	35.30
	±11.82	±13.95	±0.99	±12.78	±0.06	±0.03	±1.61
	13	13	13	13	13	13	13
1991*	343.21	549.46	132.09	502.83	1.84	1.38	37.87
	±17.54	±20.70	±1.47	±18.97	±0.09	±0.05	±2.40
	9	9	9	9	9	9	9
1992*	348.64	540.75	135.57	553.06	1.74	1.48	37.02
	±14.38	±19.82	±1.20	±15.56	±0.08	±0.04	±2.29
	11	10	11	11	10	11	10
1993*	345.23	568.35	130.45	504.76	1.97	1.40	38.24
	±8.57	±10.24	±0.72	±9.26	±0.04	±0.02	±1.18
	26	25	26	26	25	26	25

[a] Refer to page 44 for a description of performance traits

Table 9. Least squares means, standard errors and number of observations by year for performance traits[a] of Polled Hereford bulls during 140 and 112 (*)-day test periods.

	OFFICWT (KG)	OFFWT (KG)	HT365 (CM)	WT365 (KG)	CUMADG (KG)	CUMWDA (KG)	SC (CM)
1981	270.52	495.88	122.10	484.76	1.61	1.30	34.65
	±3.18	±3.66	±0.28	±3.57	±0.02	±0.01	±0.69
	211	211	212	212	212	212	89
1982	291.65	523.38	123.97	498.63	1.66	1.35	35.72
	±3.63	±4.21	±0.32	±4.11	±0.02	±0.01	±0.55
	113	113	113	113	113	113	108
1983	297.71	533.14	125.25	505.98	1.68	1.37	36.34
	±3.93	±4.55	±0.35	±4.45	±0.02	±0.01	±0.58
	97	97	97	97	97	97	96
1984	319.29	557.84	126.52	522.95	1.70	1.41	36.57
	±4.97	±5.75	±0.44	±5.62	±0.03	±0.01	±0.73
	60	60	60	60	60	60	60
1985	311.34	560.28	127.90	531.14	1.78	1.44	35.98
	±5.07	±5.86	±0.45	±5.73	±0.03	±0.01	±0.77
	59	59	59	59	59	59	57
1986	293.23	536.83	127.54	525.51	1.70	1.41	36.00
	±5.23	±6.11	±0.47	±5.98	±0.03	±0.02	±0.78
	60	59	59	59	60	59	59
1987*	360.85	563.79	129.06	523.95	1.81	1.42	36.62
	±7.11	±8.37	±0.64	±7.76	±0.04	±0.02	±1.02
	42	40	40	40	40	40	40
1988*	361.95	570.03	132.33	517.72	1.84	1.42	37.83
	±4.94	±5.86	±0.45	±5.43	±0.03	±0.01	±0.71
	102	99	99	99	99	99	99
1989*	367.96	573.01	133.17	534.66	1.83	1.45	37.19
	±4.96	±5.94	±0.45	±5.51	±0.03	±0.01	±0.72
	132	121	121	121	121	121	120
1990*	370.49	581.46	134.64	536.50	1.84	1.46	37.23
	±5.90	±7.07	±0.54	±6.56	±0.03	±0.02	±0.86
	69	65	65	65	65	65	65
1991*	368.74	579.33	136.04	552.41	1.87	1.50	38.15
	±5.64	±6.74	±0.52	±6.25	±0.03	±0.02	±0.82
	82	77	77	77	77	77	77
1992*	402.44	600.83	136.03	545.50	1.78	1.47	36.68
	±7.98	±9.50	±0.73	±8.81	±0.05	±0.02	±1.16
	53	49	49	49	49	49	49
1993*	368.01	586.03	134.95	529.53	1.94	1.47	37.85
	±7.12	±8.41	±0.64	±7.80	±0.04	±0.02	±1.02
	45	42	42	42	42	42	42
1994*	361.97	573.20	135.09	547.52	1.88	1.46	35.69
	±10.46	±12.42	±0.95	±11.51	±0.06	±0.03	±1.51
	19	18	18	18	18	18	18

[a] Refer to page 44 for a description of performance traits

Table 10. Least squares means, standard errors and number of observations by year for performance traits[a] of Limousin bulls during 140 and 112 (*)-day test periods.

	OFFICWT (KG)	OFFWT (KG)	HT365 (CM)	WT365 (KG)	CUMADG (KG)	CUMWDA (KG)	SC (CM)
1982	291.82	522.60	132.46	498.75	1.66	1.36	33.93
	±7.22	±8.20	±0.52	±6.98	±0.03	±0.02	±0.84
	39	39	39	39	39	39	39
1983	314.63	543.90	129.81	504.21	1.63	1.37	33.96
	±6.20	±7.04	±0.44	±6.00	±0.03	±0.02	±0.72
	52	52	52	52	52	52	52
1984	330.93	563.54	131.42	516.43	1.67	1.41	34.48
	±6.56	±7.45	±0.47	±6.34	±0.03	±0.02	±0.77
	47	47	47	47	47	47	47
1985	334.23	566.68	132.18	528.56	1.66	1.43	33.94
	±5.70	±6.48	±0.41	±5.51	±0.02	±0.02	±0.67
	64	64	64	64	64	64	64
1986	336.43	578.37	131.40	525.06	1.74	1.44	33.84
	±6.93	±7.86	±0.50	±6.70	±0.03	±0.02	±0.81
	47	47	47	47	47	47	47
1987*	349.92	524.31	131.88	509.16	1.56	1.35	32.67
	±9.79	±10.37	±0.78	±8.93	±0.05	±0.02	±1.32
	32	32	32	32	32	32	32
1988*	366.89	560.28	136.24	517.77	1.73	1.40	35.81
	±9.90	±10.49	±0.79	±9.04	±0.05	±0.02	±1.33
	26	26	26	26	26	26	26
1989*	361.00	569.65	135.52	527.12	1.86	1.45	35.14
	±9.28	±9.84	±0.74	±8.48	±0.04	±0.02	±1.26
	55	55	55	55	55	55	54
1990*	350.53	552.02	134.35	507.39	1.80	1.38	35.61
	±11.23	±11.91	±0.90	±10.26	±0.05	±0.01	±1.53
	30	30	30	30	30	30	28
1991*	309.17	501.20	135.60	504.11	1.71	1.38	33.46
	±5.19	±5.55	±0.42	±4.78	±0.02	±0.01	±0.71
	90	88	88	88	88	88	88
1992*	308.54	495.10	134.92	518.16	1.67	1.41	32.81
	±6.73	±7.13	±0.54	±6.14	±0.03	±0.02	±0.91
	57	57	57	57	57	57	57
1993*	325.99	510.39	133.26	488.06	1.66	1.34	32.47
	±5.90	±6.34	±0.48	±5.46	±0.03	±0.01	±0.81
	70	69	69	69	69	69	69

[a]=Refer to page 44 for a description of performance traits

Table 11. Least squares means, standard errors and number of observations by year for performance traits[a] of Charolais bulls during 140-day test periods.

	OFFICWT (KG)	OFFWT (KG)	HT365 (CM)	WT365 (KG)	CUMADG (KG)	CUMWDA (KG)	SC (CM)
1981	326.06	580.77	131.27	529.58	1.82	1.48	35.46
	±8.36	±10.47	±0.63	±12.07	±0.05	±0.03	±2.11
	115	115	109	112	115	115	35
1982	310.84	562.41	130.30	486.91	1.80	1.38	36.22
	±11.33	±14.20	±0.81	±14.44	±0.06	±0.04	±1.73
	77	77	75	77	77	77	75
1983	297.34	542.08	131.95	544.67	1.75	1.47	35.00
	±5.68	±7.12	±0.41	±7.24	±0.03	±0.02	±0.84
	93	93	93	93	93	93	71
1984	307.53	553.27	131.55	559.15	1.76	1.43	34.50
	±6.30	±7.90	±0.45	±8.03	±0.04	±0.02	±0.88
	76	76	76	76	76	76	67
1985	314.80	576.41	131.45	535.49	1.51	1.36	35.40
	±9.51	±12.94	±0.77	±13.69	±0.05	±0.03	±1.45
	34	28	26	26	34	34	24
1986	333.40	598.75	130.68	579.36	1.85	1.56	36.13
	±27.30	±34.22	±1.96	±34.80	±0.20	±0.09	±3.49
	4	4	4	4	4	4	4

[a]=Refer to page 44 for a description of performance traits

Table 12. Least squares means, standard errors and number of observations by year for performance traits[a] of Gelbvieh bulls during 112-day test periods.

	OFFICWT (KG)	OFFWT (KG)	HT365 (CM)	WT365 (KG)	CUMADG (KG)	CUMWDA (KG)	SC (CM)
1988	382.69	603.90	134.81	543.84	1.98	1.50	38.79
	±12.03	±13.57	±0.87	±12.92	±0.06	±0.04	±1.39
	21	21	21	21	21	21	21
1989	366.14	595.30	135.67	570.75	2.05	1.56	39.14
	±13.34	±15.04	±0.97	±14.33	±0.06	±0.04	±1.54
	14	14	14	14	14	14	14
1990	346.57	544.92	134.25	537.80	1.77	1.47	38.25
	±17.94	±20.22	±1.30	±19.26	±0.09	±0.06	±2.07
	7	7	7	7	7	7	7
1991	325.76	540.46	136.95	560.82	1.92	1.54	37.03
	±10.66	±12.02	±0.77	±11.45	±0.05	±0.03	±1.23
	34	34	34	34	34	34	34
1992	301.58	535.17	135.84	571.20	2.01	1.54	36.75
	±12.13	±13.96	±0.88	±13.02	±0.06	±0.04	±1.43
	16	15	16	16	16	16	15
1993	318.75	519.85	136.99	573.18	1.78	1.55	36.76
	±7.79	±9.24	±0.56	±8.36	±0.04	±0.02	±0.95
	40	38	40	40	40	40	38

[a]=Refer to page 44 for a description of performance traits

Table 13. Least squares means, standard errors and number of observations by year for performance traits[a] of Simmental bulls during 112-day test periods.

	OFFICWT (KG)	OFFWT (KG)	HT365 (CM)	WT365 (KG)	CUMADG (KG)	CUMWDA (KG)	SC (CM)
1989	401.49	613.47	140.48	564.34	1.90	1.55	39.32
	±11.48	±12.07	±0.84	±10.07	±0.04	±0.03	±1.12
	43	42	42	42	42	42	42
1990	341.91	543.46	134.86	516.10	1.81	1.40	37.94
	±9.65	±10.98	±0.77	±9.17	±0.04	±0.02	±1.02
	42	37	37	37	37	37	37
1991	364.83	570.30	138.59	548.80	1.76	1.47	38.15
	±13.66	±15.46	±1.08	±12.91	±0.06	±0.03	±1.43
	24	20	20	20	20	20	20
1992	364.63	566.59	139.76	547.74	1.81	1.48	37.22
	±8.38	±8.87	±0.62	±7.41	±0.03	±0.02	±0.82
	66	63	63	63	63	63	63
1993	340.10	551.82	136.07	522.98	1.80	1.49	38.60
	±9.83	±13.81	±0.96	±11.53	±0.05	±0.02	±1.28
	41	22	22	22	22	37	22

[a]=Refer to page 44 for a description of performance traits

Table 14. Phenotypic correlations between price and performance traits[a], with significance levels reported, for Angus (AN), Brangus (BR), Hereford (HF), Polled Hereford (PH), Charolais (CH), Limousin (LM), Simmental (SM) and Gelbvieh(GB) bulls

	OFFICWT	OFFWT	HT365	WT365	CUMADG	CUMWDA	SC	INDEX
(AN)	.23	.46	.26	.46	.41	.45	.17	.52
1202[c]	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
(BR)	.28	.44	.28	.38	.32	.42	.23	.45
201[c]	(.0002)	(.0001)	(.0002)	(.0001)	(.0001)	(.0001)	(.0022)	(.0001)
(HF)	.15	.38	.44	.42	.37	.44	.23	.51
159[c]	(.0894)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0098)	(.0001)
(PH)	.32	.47	.36	.42	.34	.46	.12	.47
387[c]	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0218)	(.0001)
(CH)[b]	.17	.26	.46	.43	.18	.39	.13	.46
51[c]	(.2573)	(.0898)	(.0015)	(.0031)	(.2284)	(.0073)	(.3784)	(.0014)
(LM)	.29	.42	.38	.45	.23	.50	.13	.50
252[c]	(.0001)	(.0001)	(.0001)	(.0001)	(.0004)	(.0001)	(.0603)	(.0001)
(SM)[b]	.37	.36	.25	.52	-.02	.51	.07	.35
86[c]	(.0016)	(.0018)	(.0375)	(.0001)	(.8674)	(.0001)	(.5514)	(.0026)
(GB)[b]	.25	.41	.40	.46	.44	.46	.33	.53
81[c]	(.0363)	(.0005)	(.0006)	(.0001)	(.0002)	(.0001)	(.0057)	(.0001)

[a]=Refer to page 44 for a description of performance traits

[b]=Charolais bulls represent 140-day test data; Simmental and Gelbvieh bulls represent 112-day test data

[c]=Number of observations

Table 15. Partial Regressions of Sale Price on Performance Traits for Angus (AN), Brangus (BR), Hereford (HF), Polled Hereford (PH), Charolais (CH), Limousin (LM), Simmental (SM) and Gelbvieh (GB) bulls tested over 140 and 112-day test periods

Number	(AN) 1206	(BR) 212	(HF) 160	(PH) 387	(CH)[e] 51	(LM) 252	(SM)[e] 86	(GB)[e] 81
OFFICWT			-7.10	4.15		3.37		
($/KG)[a]			(2.11)[c]	(1.03)[c]		(1.28)[c]		
			.0010[d]	.0001[d]		.0090[d]		
OFFWT	2.81	3.41	9.35					
($/KG)[a]	(.69)[c]	(1.25)[c]	(2.26)[c]					
	.0001[d]	.0069[d]	.0001[d]					
HT365	17.27	28.59	65.53	29.59	36.38	48.76		32.77
($/CM)[a]	(5.31)[c]	(12.77)[c]	(21.19)[c]	(11.92)[c]	(16.30)[c]	(17.87)[c]		(16.13)[c]
	.0012[d]	.0264[d]	.0025[d]	.0135[d]	.0310[d]	.0069[d]		.0462[d]
WT365	4.53			3.09			6.61	
($/KG)[a]	(.73)[c]			(1.20)[c]			(1.42)[c]	
	.0001[d]			.0107[d]			.0001[d]	
CUMADG	1016.60	943.04		1099.41				
($/KG)[a]	(98.33)[c]	(263.56)[c]		(195.22)[c]				
	.0001[d]	.0004[d]		.0001[d]				
CUMWDA								
($/KG)[a]								
SC			20.87					25.24
($/CM)[a]			(9.45)[c]					(9.44)[c]
			.0290[d]					.0095[d]
INDEX					17.84	63.63		26.45
($/UNIT)[a]					(7.85)[c]	(9.86)[c]		(7.09)[c]
					.0283[d]	.0001[d]		.0004[d]
R^{2b}	.5212	.5876	.5449	.4404	.4573	.4282	.3922	.5812

[a]=Change in price per unit change indicated for each trait

[b]=Proportion of variation in price accounted for by traits having coefficients in that particular breed

[c]=Standard error of estimate

[d]=Significance level

[e]=Charolais bulls were on 140-day test; Gelbvieh and Simmental bulls were on 112-day test; all other breeds include both 140 and 112-day data

Table 16. Correlations between individual expected progeny differences and performance traits[a], with significance levels reported, for Angus bulls

	EPDs			
	BIRTH	WEANING WEIGHT	YEARLING WEIGHT	MILK
OFFICWT	.15 (.0004)	.17 (.0001)	.17 (.0009)	-.02 (.5358)
OFFWT	.24 (.0001)	.19 (.0001)	.22 (.0001)	.01 (.7612)
HT365	.34 (.0001)	.20 (.0001)	.08 (.0931)	-.13 (.0016)
WT365	.13 (.0020)	.23 (.0001)	.24 (.0001)	.07 (.0806)
CUMADG	.16 (.0022)	.05 (.2142)	.11 (.0269)	.06 (.1196)
CUMWDA	.20 (.0001)	.20 (.0001)	.19 (.0001)	.03 (.5211)
SC	.02 (.7224)	-.06 (.1220)	-.12 (.0139)	.07 (.0017)
INDEX	.20 (.0001)	.13 (.0006)	.18 (.0003)	.07 (.0731)

[a]=Refer to page 44 for a description of performance traits

Table 17. Correlations between individual expected progeny differences and performance traits[a], with significance levels reported, for Polled Hereford bulls

	EPDs			
	BIRTH	WEANING WEIGHT	YEARLING WEIGHT	MILK
OFFICWT	.18 (.0275)	.15 (.0728)	.18 (.0380)	-.04 (.6064)
OFFWT	.19 (.0262)	.14 (.1096)	.20 (.0202)	-.02 (.7732)
HT365	.28 (.0008)	.15 (.0809)	.22 (.0080)	-.20 (.0202)
WT365	.06 (.4883)	.06 (.4810)	.08 (.3564)	-.07 (.4394)
CUMADG	.05 (.5758)	.01 (.9322)	.09 (.3136)	.03 (.7664)
CUMWDA	.07 (.4209)	.07 (.4181)	.11 (.1837)	-.03 (.6838)
SC	.07 (.4162)	.01 (.9052)	.01 (.8733)	-.04 (.6245)
INDEX	.07 (.4194)	.05 (.5505)	.11 (.2032)	-.03 (.6819)

[a]=Refer to page 44 for a description of performance traits

Table 18. Correlations between individual expected progeny differences and price, with significance levels reported, for Angus and Polled Hereford bulls

EPDs	ANGUS	POLLED HEREFORD
BIRTH	-.10 (.0655)	.02 (.8257)
WEANING WEIGHT	.19 (.0004)	.11 (.2221)
YEARLING WEIGHT	.24 (.0001)	.12 (.1700)
MILK	.27 (.0001)	.09 (.3085)

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Master of Science

Thesis: RELATIONSHIPS BETWEEN PERFORMANCE TRAITS AND INDIVIDUAL EXPECTED PROGENY DIFFERENCES IN A BEEF PERFORMANCE TESTING PROGRAM AND THEIR EFFECT ON SALES PRICE

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