HETEROSIS IN SIMMENTAL-ANGUS ROTATIONAL CROSS CALVES

by

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INTRODUCTION

Heterosis was first coined by Shull in 1914 to describe the increased vigor of crossbreds relative to their parents (Sheridan, 1981). Today, crossbreeding is widely used in commercial beef production as a means of exploiting heterosis when the desired phenotype is a combination of existing breeds. Systematic crossbreeding provides for use of heterosis and differences among breeds to optimize average genetic merit of performance traits for adaptability to various climatic and nutritive environments in beef production (Dickerson, 1983; Gregory and Cundiff, 1980). Maximum heterosis can be achieved through breeds that are as genetically diverse as possible, but still complementary.

In the beef cattle industry, heterosis can be best utilized by the cow-calf producer. Many commercial cattlemen use the established breed of cows in their operation and cross them with a bull of a different beef breed. Weaning weight is a direct measure of the major product from the beef cow herd. For most cow-calf producers, weaning weight constitutes a large portion of their income and any heterotic effects would be of direct benefit. However, reproductive, preweaning and postweaning traits are also important to the cow-calf producer, feedlot operator and packer, because all phases of the cattle industry are intricantly meshed.

Important reproductive traits include fertility, gestation length, calving ease and percent of calves surviving to weaning. The percent of calves surviving to weaning may be the most important reproductive trait in terms of monetary profit or loss. Although the importance of producing a live calf with calving ease and acceptable birth weights is the first major step in weaning a calf, producers need calves that can quickly and efficiently grow from birth to weaning and continue that growth to slaughter and obtain acceptable mature size..

Angus cattle lead the purebred beef industry in the total number of registrations per year. This also indicates Angus cattle must be used extensively in the commercial cow-calf industry. Simmental cattle have also experienced a rapid surge in popularity among purebred breeders in recent years, and more commercial cattlemen are incorporating Simmental cattle into their breeding regimes. However, there are relatively few research reports which document the performance of crossbred Simmental cattle. Thus, a two-breed rotational crossbreeding system using Angus and Simmental cattle was initiated in southeast Kansas, where much of the income is derived from cow-calf operations. Using a rotational crossbreeding system, only replacement sires must be obtained from the purebred industry. All aspects of the beef cattle industry were investigated; reproductive, preweaning, postweaning and carcass traits. The objectives of the study were:

1. Characterize the crossbred calves that best fit the needs of the producer in southeast Kansas by determining what percentage of Simmental and British breeding provides optimum growth in all aspects of the cattle industry; reproductive, preweaning, postweaning and carcass traits.
2. Estimate heterosis values for gestation length, birth weight, weaning weight and yearling weight.
3. Document the loss of heterosis between generations associated with a two-breed rotational crossbreeding system.

LITERATURE REVIEW

Fertility

Fertility or reproductive performance is expressed as the percentage of calves born to cows exposed to breeding (Turner et al., 1968). Results from several studies collectively indicate that fertility heterosis is large and can be of considerable importance.

Gaines et al. (1966) reported increased calf crop percentages of 5.9% in two and three breed cross calves compared to straightbreds. Studies by Wiltbank et al. (1967) showed a 3% heterotic effect in reproductive performance associated with breeding straightbred cows to produce crossbred calves. Crossbred calves from straightbred cows in trial 1 showed a 3% advantage in calves born over straightbred cows with straightbred calves. However, in trial 2, straightbred cows with straightbred calves exceeded the dams with crossbred calves.

Much of the heterosis is expressed in crossbred cows. All possible crosses of Angus, Hereford, Brahman and Brangus cows produced 9.6% more calves than straightbred cows with crossbred calves of the same four base breeds (Turner et al., 1968). Koger et al. (1962) also indicated crossbred cows produced more calves under various pasture conditions in Florida, giving 8.8% heterosis.

Gaines et al. (1978a) reported 2.1% increase in reproductive performance in British blood crossbred cows over straight British breed cows, but indicated it was more important to have crossbred calves than cows, considering the favorable environment in Virginia.

In a review article, Cundiff (1970) stated the primary benefit of heterosis might be expected in fertility and maternal ability of crossbred cows. This was further indicated by 4.6% heterosis present in British-bred crossbred cows for number of calves born compared to 1.5% heterosis for straightbred British breeds crossed with a different British breed bull.

In a three generation rotational crossbreeding study using Angus, Hereford and Brahman crosses, Crocket et al. (1978a), reported 4.9% heterosis in pregnancy rate. In a similar study using Angus, Polled Hereford and Santa Getrudis crosses, Neville et al. (1984a) reported crossbreeding increased calving rate by 3.6% over straightbreeding.

Calf Survival to Weaning

In a review article, Long (1980) indicated that heterosis for percentage calf crop weaned was 1-16% in breed diallels and 4-14% in studies characterizing sire breeds. Cundiff (1970) stated average heterosis for calf survival to weaning was 4.1%.

Gaines et al. (1966) reported ten more calves weaned per 100 crossbred cows bred or 4.6% heterosis. These included two and three breed Angus, Hereford, and Shorthorn cross calves born in the first phase of a Virginia trial. However in the second phase of the experiment, straightbred cows weaned .7% more calves than crossbred cows (Gaines, et al., 1978a). It was also noted that there was little difference in terms of total return to the cow/calf producer between crossbred and straightbred cows. Similiar results were reported by Wiltbank et al. (1967). In two breed crosses with Angus, Hereford and Shorthorn cattle, 3.7% more crossbred calves were present at weaning.

It was noted by Rollins et al. (1968), using Angus, Shorthorn and Hereford two-breed crosses, that relatively larger crossbred calves at birth may indicate greater hybid vigor in embryonic growth and development, but may cause greater calving difficulties. This depressed hybrid vigor in percent of calves weaned. Heterosis of 1.3% was reported for the three two breed crosses.

Five years of reproductive data using four straightbred and twelve types of crossbred Angus, Brahman, Brangus and Hereford cows were examined by Turner et al. (1967). The study resulted in 15.6% increase in calves weaned by the crossbred cows over straightbred cows.

Cundiff et al. (1974) reported crossbred cows weaned 6.4% more calves than straightbred cows. However, the difference was due to significantly higher pregnancy rates and first service conception rates in the crossbred females rather than greater survival of the calves after birth.

Matings involving Angus, Brahman, Hereford and all possible two-breed rotational crosses were analyzed over three generations by Crockett et al. (1978b). Heterosis for calf survival to weaning decreased over successive generations with an average of 7.9% more crossbred calves than straightbred calves at weaning. The decline was due to greater improvement in survival among the straightbreds over generations than crossbreds. Similiar results were reported by McElhenney et al. (1985) in a five breed diallel using Angus, Brahman, Hereford, Holstein and Jersey cattle. Heterosis for calf survival to weaning was 8.7%.

In a three breed rotational cross comprised of Angus, Polled Hereford and Santa Getrudis, Neville et al. (1984a), reported 2% heterosis for calf survival until weaning. It was noted that significant and positive heterosis occured when British and Brahman breeds were compared and the weaning rate of one or both of the straightbreds was less than 80%.

Lawlor et al. (1984) made breed group comparisons of calves sired by Hereford, Angus, Simmental-Hereford and Simmental bulls bred to Hereford cows. Straightbred Herefords and Angus-Hereford cross calves had the highest weaning rate with the 50% Simmental calves having the lowest. None of the postnatal mortalities were dystocia related in the 50% Simmental sired calves and no explanation was apparent.

Three studies have reported negative heterosis for percentage calf crop weaned. Peacock et al. (1977) using two breed cosses of Angus, Brahman and Charolais, reported -.1% heterosis. Hereford, Angus, Red Poll, Charolais and Brahman cross cattle in Nevada produced -.04% heterosis for percentage calf crop weaned (Bailey, 1981). Of the females exposed to bulls, 81% weaned calves in the Nevada study. Koch et al. (1985) reported -.05% heterosis for percentage calf crop weaned from Angus and Hereford crosses.

Gestation Length

Reported heterosis estimates for gestation length have been near zero (Long, 1980). Gerlaugh et al. (1951) used 397 Hereford, Angus and Herford-Angus cross calves in Ohio. Hereford cows mated to Hereford bulls had average gestation length of 286 d compared to 276.5 d for Angus mated to Angus. The crossbred calves were intermediate in gestation length, with the Hereford sired calves having longer gestation lengths than the Angus sired calves. All differences between breeds and crosses were significant indicating sire breed has a significant effect on gestation length. Gestation length for male calves was one day longer than for female calves. Heterosis of .4% was reported for gestation length. Similiar results were reported by Rollins et al. (1968) using two-breed crosses of Hereford, Angus and Shorthorn. Heterosis for gestation length was .34%.

Fort Robinson data using Hereford, Angus and Shorthorn cattle indicated average conception dates for female embryos were 2.8 d earlier than male embryos (Cundiff et al., 1974). Gestation length was 1.2 d shorter for female calves causing females to be born four days earlier than males. Crossbred cows conceived 2.8 d earlier than straightbred cows but the advantage was offset by a 1.2 d longer gestation length. Overall, heterosis for gestation length was .4%. Similiarly, McElhenney et al. (1985) using Angus, Brahman, Hereford, Holstein and Jersey cattle, reported male calves had a 1.3 d longer gestation period than female calves. Fall born calves exhibited longer gestation lengths than calves born other times of the year. Heterosis of .1% for gestation length was reported.

In analyzing 1207 calves in a four breed diallel crossing design including Red Poll, Brown Swiss, Hereford and Angus breeds, -.1% heterosis was reported by Gregory et al. (1978a) for gestation length. It was also shown that gestation length was 1.4 d longer in male than in female calves.

Calving Ease

Calving ease is composed of two parts, individual and maternal. Individual calving ease indicates the ability of a calf to be born while maternal calving ease gives an indication of a cow's ability to undergo parturition.

In Long's review article (1980), he stated few studies have reported heterosis values for calving ease, with 0 to 7% being published.

Two-breed cross calves of Angus, Charolais and Hereford cows were evaluated for calving ease by Sagebiel et al. (1969). Heterosis of 6.4% was reported for crossbred calves. Straightbred cows exhibited increased dystocia with crossbred heifer calves. Cundiff et al. (1974) reported increased dystocia in crossbred calves using Angus, Hereford and Shorthorn cattle. Heterosis was .05% for calving ease in this study.

Long and Gregory (1974) reported heterosis of 1.3% from a study of Angus, Hereford and reciprocal cross calves for calving ease. Male calves exhibited 14.5% more dystocia than heifer calves. Gregory et al. (1978b) reported the difference in calving difficulty between male and female calves became greater as the average level of calving difficulty increased among breeds. Crossbred and straightbred male calves sired by Red Poll, Brown Swiss, Hereford and Angus had 4.9% more calving difficulties. Overall, crossbred calves had 2.3% more calving difficulties than straightbred calves.

McElhenney et al. (1985) reported -.6% heterosis for calving ease using Angus, Brahman, Hereford, Holstein and Jersey cattle in a five breed diallel. Calving difficulties increased for both straightbred and crossbred first calf heifers. It was noted as mature size increased among breeds, more calving difficulties arose.

In Hereford and Angus F_1, backcross, F_2 and F_3 inter se combination work, Koch et al. (1985) reported non-significant heterosis of -.7% for calving ease. The negative heterosis value was attributed to the high percentage of unassisted births. Two year old heifers had significantly more difficult parturitions than older cows. Reported heterosis for the two year old heifers was -1.7%. Koch et al. (1985) noted calving ease was negatively correlated with birth weight and positively correlated with survival of calf until weaning. In this same study, significant 1.2% heterosis was reported for maternal calving ease. Angus heifers had 8.6% more unassisted births than other straightbreds and crossbreds. Maternal calving ease heterosis for two year old crossbred heifers was -.4%. Sagebiel et al, (1969) also reported crossbred cows had more difficulty calving than straighbred cows.

Milk Production

Hereford, Angus and Shorthorn straightbred and crossbred cows were evaluated for milk production at the Fort Robinson Beef Cattle Research Station (Cundiff et al., 1974). Milk consumption on 149 crossbred calves and 101 straightbred calves was evaluated at two, six, 14 and 29 weeks (weaning) after birth. The effects of milk production heterosis was significant at six weeks and 29 weeks after calving. Milk production of crossbred cows over straightbred cows were increased by .9% at two weeks, 7.5% at six weeks, 6.1% at 14 weeks and 38% at 29 weeks. The greater and especially more persistant lactation of crossbred cows was reflected in increased effects of maternal heterosis on weight gain from birth to weaning.

Crossbred Brahman and Angus cows also produced consistently more milk than Brahman or Angus (Criss et al., 1985). Heterosis was 47.4% for 12 hour milk production in the crossbred cows. Crossbred cows were intermediate in butterfat percent and total solids production.

Birth Weight

In a review by Long (1980), average heterosis for birth weight ranged from 1 to 11% with a mean of 4%. Gaines et al. (1966) and Gregory et al. (1965) both reported heterosis of 3.8% using Angus, Shorthorn and Hereford straightbred and two-breed crossbred cattle. Straightbred Angus calves were significantly lighter than Hereford or Shorthorn calves at birth. There was little evidence of maternal influence reported. Koch et al. (1985) also reported straightbred Angus had lighter birth weights, but both individual and maternal heterosis was significant. Individual birth weight heterosis was 2.6% while maternal heterosis was 3.2% in Angus-Hereford cross calves. Rollins et al. (1969) and Long and Gregory (1974) reported individual heterosis results of 4.55% and 3.1% with Angus, Shorthorn and Hereford crossbred calves.

Gerlaugh et al. (1951) reported larger birth weights for crossbred calves out of Angus cows than straightbred calves. He noted the birth weights increased steadily throughout the study due to cow age with 1.1% heterosis. Similiar results were reported by Pahnish et al. (1969) using Hereford, Angus and Charolais cattle.

Heterosis reported was 4.4% for bull calves and 1.4% for heifer calves, with overall heterosis of 2.9%.

Gaines et al. (1978a) reported 1.0 kg heavier birth weights from females out of crossbred cows than heifers from straightbred cows. Bull calves were .8 kg heavier out of crossbred cows than straightbreds. Both cow size and heterosis contributed to birth weight differences with 2.8% heterosis.

Male calves were 2.3 kg heavier than female calves at birth using Red Poll, Brown Swiss, Hereford and Angus cross cattle in a USDA Meat Animal Research study (Gregory et al., 1978b). Average heterosis for birth weight was 2.3%. Parker et al. (1972) reported no heterosis in Charolais and Hereford straightbred and reciprocal cross calves. Angus, Polled Hereford and Santa Getrudis calves were compared in a two and three breed rotational crossbreeding program by Chapman et al. (1970). Birth weight heterosis was .3%. Birth weight heterosis of .7% was reported by Neville et al. (1984b) in a similiar study with the same three breeds over three generations.

In south Florida, three generations of Angus, Brahman and Hereford two-breed and three-breed crosses were evaluated for birth weight (Crockett et al., 1978b). Heterosis increased for the two breed rotational crosses over generations. Heterosis was 7%, 10% and 11% for the three generations with overall heterosis of 9.4%. In a five breed diallel, McElhenney et al. (1985) reported birth weight heterosis of 4.3%. Both straightbred and crossbred male calves were heavier than heifer calves. Calves born in the spring had the heaviest birth weights. Fall calves were the lightest at birth with winter and summer born calves being intermediate.

Preweaning Average Daily Gain

Heterosis can be a major influence in preweaning average daily gain (preweaning ADG), and heterosis may be different for males and females (Long, 1980). Gregory et al. (1965) reported heterosis effects were greater for females than males using Hereford, Angus and Shorthorn with 4.8% heterosis overall for preweaning ADG. Sagebiel et al. (1974) also found females gaining faster from birth to weaning than males. It was noted that two-breed crossbred calves of both sexes gained significantly faster than straightbred Angus, Hereford or Charolais. Heterosis for preweaning ADG for females, males and overall were 4.3%, 3.6% and 4%, respectively.

In three contrasting studies, it was found males outgained females from birth to weaning. Two breed cross steers showed significant 3.7% heterosis, while heifers showed no heterosis in a study using Hereford, Angus and Charolais straightbred and cross cattle (Pahnish et al., 1969). Overall heterosis for preweaning ADG was 2.85%. Long and Gregory (1974), using Hereford and Angus cross cattle, also showed steers had higher preweaning ADG. Overall, the two-breed cross exhibited 8.2% heterosis. The heterosis differences between the sexes were generally small and insignificant. Results from a study involving Red Poll, Angus, Polled Hereford and Santa Getrudis indicated heterosis significantly increased postnatal preweaning ADG (Gregory et al., 1978b). There was significantly higher heterosis in male calves over female calves involving all two breed crosses. Combined heterosis of 4.2% was observed for both sexes.

Gaines et al. (1966) reported 3.8% heterosis in preweaning ADG for two breed crosses of Angus, Hereford and Shorthorn. Three breed crosses exhibited half as much individual heterosis as two-breed crosses. Similiar results of 5.2% preweaning ADG heterosis was shown over three generations of Angus, Polled Hereford and Santa Getrudis crosses by Neville et al. (1984b) and Angus-Hereford crosses had 4.1% heterosis for preweaning ADG in a study reported by Koch et al. (1985).

In a study using Angus, Brahman, Hereford, Holstein and Jersey cattle, McElhenney et al. (1985) reported preweaning ADG heterosis of 9.3% for crossbred calves over straightbred calves. He noted calves born in the winter months had the highest preweaning ADG with those born in summer gaining slower than all other calves.

Weaning Weight

Many studies have reported weaning weight heterosis with a resulting range of 3 to 16% and an average of 5% (Long, 1980). Gerlaugh et al. (1951) using Hereford and Angus in a two-breed cross, reported weaning weight heterosis of 4.8%. Similiar results were reported by Koch et al (1985) with 3.34% heterosis. Long and Gregory (1974) reported 7.2% weaning weight heterosis with two breed crosses of Hereford and Angus. Steer calves were not significantly heavier than heifers in this study.

Heterosis was slightly greater in heifer calves than bull calves in a two breed Angus, Shorthorn and Hereford study reported by Gregory et al. (1965). Overall weaning weight heterosis was 4.7%. This result agreed with Rollins et al. (1969) and Gaines et al. (1966), who reported heterosis values of 4.5% and 4.7% respectively.

Gaines et al. (1978a) reported weaning weight heterosis results from the second phase of the Virginia work. Heifers exhibited more heterosis than steer calves (4.3% vs 2.9%) for weaning weight. Heifers and steers from crossbred cows weighed significantly more than offspring from straightbred cows. The difference was attributed to cow weight (20%) and heterosis (80%). Overall weaning weight heterosis was 3.6%.

Weaning weight of calves raised by Charolais-Hereford F_1 cows had 5% more heterosis than crossbred calves raised by straightbred cows (Klosterman et al. 1968). Sagebiel et al. (1974) reported crossbred calves of both sexes weighed significantly more at 205 d of age than straightbred calves using Angus, Hereford and Charolais crosses. There was also greater heterosis in females than males. Heterosis was 3.8% for females, 3.2% for males and 3.5% overall. Pahnish et al. (1969) reported more heterosis in males than females with the same breeds. Analyzing two-breed crosses, heterosis for males and females was 3.8% and 1.9%, respectively, with 2.85% weaning weight heterosis when combining both sexes.

In a four breed diallel using Red Poll, Angus, Hereford and Brown Swiss, Gregory et al. (1978b) reported significant weaning weight heterosis for all two breed crosses at 3.8%. This was similiar to 2.4% heterosis from a study using Hereford, Red Poll, Angus and Charolais-cross heifers in Nevada (Bailey, 1981). Peacock et al. (1981) reported 8.8% heterosis in 205 d weight in Angus, Brahman and Charolais crosses.

Differences in Bos taurus and Bos Indicus cattle were shown in a three generation study using Angus, Hereford and Brahman cattle (Crockett et al., 1978b). Heterosis for weaning weight in Angus-Hereford, Angus-Brahman and Hereford-Brahman crosses were 5%, 17% and 18%, respectively. Disregarding breed, heterosis in the three generations was 15%, 9% and 17%. In a five breed diallel using Angus, Brahman, Hereford, Holstein and Jersey cattle, weaning weight heterosis was 8.4% (McElhenney et al., 1985).

MacNeil et al. (1982) used South Dakota Beef Improvement Records to study weaning weight heterosis in Red Angus, Hereford, Angus, Polled Hereford, Shorthorn, Tarentaise, Gelbvieb, Limousin, Chianina, Charolais, Simmental and Maine Anjou cattle. Two breed crossbred calves had maximum individual heterosis of 4.4%. Calves with F_1 crossbred dams were 6.8% heavier than crossbred calves with straightbred dams.

In two seperate reports, Neville and co-workers used Angus, Polled Hereford and Santa Getrudis cattle to estimate weaning weight heterosis. Three generations of two breed crossbred calves were studied resulting in weaning weight heterosis of 5.1% (Neville et al., 1984b). Evaluating straightbred and crossbred calves as possible sires, reported heterosis was 5.2% for 205 d weight (Neville et al., 1985).

Postweaning Average Daily Gain

Most of the early crossbreeding projects centered around feedlot performance. Gerlaugh et al (1951) seperated steers from heifers and calculated postweaning average daily gain (ADG). Both sexes were placed on pasture after weaning and later moved to the feedlot. Weaning weights of the crossbred were greater than the straightbred resulting in slower pasture gain by the crossbred. ADG heterosis on pasture was .95% and 2.6% for males and females and 3.6% and 1.6% in the feedlot for males and females.

Gregory et al. (1966a) found significant heterotic effects in ADG in two breed cross heifers composed of Hereford, Angus and Shorthorn breeds. Crossbred heifers exhibited 14.88% heterosis. Gregory indicated heterosis may be greatest under a particular feeding regime that results in relatively low levels of gainability and/or heterosis decreases with increasing age after one year of age.

Vogt et al. (1966) reported feedlot ADG for two breed Angus, Hereford and Shorthorn heifers exceeded straightbred heifers by 30 g/d or 3.9% heterosis. Steers were placed on pasture for twelve months prior to being put in the feedlot. Two breed cross steers on pasture obtained 8.4% ADG heterosis and 1.16% in the feedlot.

Sagebiel et al. (1967) using Angus, Charolais and Hereford had 6.95% heterosis in feedlot calves. Jain et al. (1971) using the same three breeds, looked at differences in ADG in long and short fed heifers. Heterosis in short fed heifers was 8% and 3 to 5% in long fed heifers. It appeared heterosis decreased with increasing age of the animal.

Angus, Hereford and Charolais crossbred and straightbred steers were either placed in the feedlot directly after weaning or put on pasture before going into the feedlot in a study by Lasley et al. (1973). Steers placed in the fedlot after weaning had 7.1% heterosis. There was no apparent heterosis in long fed steers on pasture and 2.8% heterosis for the long fed steers in the feedlot. Gains on pasture may not have been rapid enough for genetic differences among the steers to be expressed.

Hereford and Angus crossbred calves exhibited 6% higher ADG from weaning to slaughter than straightbred calves with no discernible differences among steers and heifers in a study reported by Long and Gregory (1975a). It also appeared in this study that heterosis is more evident at higher rates of gain. Heterosis also tends to decrease as age of the animal increases.

The second phase of Virginia work with Hereford, Angus and Shorthorn, showed few biologically significant differences with reguard to postweaning traits (Gaines et al, 1978b). Since crossbred calves out of crossbred dams showed no apparent heterosis, influence of breeding may be decreased postweaning.

Gregory et al. (1978d) concluded most heterosis was observed in preweaning traits with crossbred steers using Red Poll, Hereford, Angus and Brown Swiss cattle. Postweaning ADG heterosis of 2.45% was obtained compared to 3.8% weaning weight heterosis indicating ADG heterosis may decrease as age increased. Neville et al. (1984c) reported similiar ADG heterosis of 2.1% for crossbred Angus, Polled Hereford and Santa Getrudis. Opposite results were shown for heifers in a Virginia study (Gaines et al., 1978b) with most of the heterosis obtained for heifers between 200 and 400 d of age. ADG heterosis was reported at 7.2%, emphasizing heterosis may be expressed at an earlier age in steers than heifers.

Yearling Weight

Yearling weight is a combination of weaning weight and postweaning ADG. Long (1980) reported yearling weight heterosis of 2 to 7% with an average value of 4%.

Gregory et al. (1966a,b) reported heterosis for steers and heifers in crossbred Angus, Hereford and Shorthorn. Heterosis of 4% and 6.9% were expressed for males and females. Vogt et al. (1966) reported 5.3% heterosis for crossbred Angus, Hereford and Shorthorn steers. Gregory et al. (1978c,d) reported

3.6% yearling weight heterosis for heifers and 3.5% for steers using Angus, Hereford, Brown Swiss and Red Poll.

Long et al. (1979a,b) reported average heterosis estimates for yearling weight of 9, 10 and 14% for pastured heifers, fed bulls and fed heifers from a modified diallel involving Angus, Brahman, Hereford, Holstein and Jersey cattle.

Carcass Traits

Cundiff (1970) stated heterosis effects were large for carcass traits associated with growth but small for most other carcass characteristics. Gregory et al. (1978e) indicated heterosis displayed in carcass traits was primarily through heterosis on weight.

Most studies involving carcass traits adjusted values for carcass weight and/or age. Long (1980) reported average heterosis of 3% for ribeye area. Gaines et al. (1967) reported 3.9% and 3.6% heterosis in crossbred Angus, Hereford and Shorthorn heifers and steers, respectively, for ribeye area. There was some indication that heterosis was apparent after adjustment for carcass weight.

Long and Gregory (1975b) reported as time on feed increased, heterosis for carcass characteristics decreased. Also, heterosis for ribeye area was decreased when carcass weight was used as a covariate indicating weight plays an important role in determining carcass trait heterosis. Heterosis was 4.6% without covariates in the model and 1.7% with carcass weight as a covariate.

Gregory et al. (1978e) reported ribeye area heterosis adjusted for age and carcass weight in Red Poll, Angus, Hereford and Brown Swiss crossbreds and straightbreds. Age adjusted ribeye area heterosis was non-significant at -1%.

Heterosis adjusted for carcass weight was significant at -2.6% for crossbreds. Gregory stated heterosis that was non-significant for age adjusted traits, but significant when adjusted for carcass weight, was due to chance. In contrast, another study using Angus, Hereford and Shorthorn found 2.5% age adjusted ribeye heterosis (Gregory et al., 1978a).

Gaines et al. (1978b) reported significant heterosis for ribeye area after adjusting for carcass weight in steers and heifers. Heifers displayed -1.5% heterosis and -.7% for steers out of Angus, Hereford and Shorthorn crossbred cows. Similiar results of -.96% heterosis were reported by Neville et al. (1984c) using Santa Getrudis, Polled Hereford and Angus crossbred cattle.

Gaines et al. (1967) found .5 mm more external fat covering in crossbred Angus, Hereford and Shorthorn than straightbred steers. Heterosis of .46% was neither biologically or statistically significant. Crossbred heifers also had non-significant heterosis of 1.4% for backfat thickness. Gregory et al. (1966b) found 13% heterosis in Angus, Hereford and Shorthorn crossbred steers for backfat thickness corrected to a constant age. Gaines et al. (1971) reported 5.1% and 3.4% heterosis for backfat for crossbred steers and heifers.

Long and Gregory (1975b) used carcass weight as a covariate or included no covariate in the model to determine backfat thickness and kidney, heart and pelvic fat (KHP). Heterosis for backfat thickness was 8.2% for no covariate and 4.5% using carcass weight as a covariate. KHP heterosis was 3.8% without the covariate and 1.3% with the covariate for crossbred Angus and Hereford steers. Similiar results for backfat thickness adjusted for age or carcass weight were reported by Gregory et al. (1978a). Heterosis for backfat adjusted for age was

8.9% and 3.8% when adjusted for carcass weight. KPH heterosis was 0% in both analyses.

There appears to be much variation of heterosis for quality grade. Long (1980) reported -3% to 3% heterosis in quality grade with average heterosis of 1%. Gregory et al. (1966a) reported 2.8% heterosis for quality grade in Angus, Hereford and Shorthorn cross steers adjusted for age. Neville et al. (1984c) reported a similiar 2.5% heterosis using Santa Getrudis, Polled Hereford and Angus cross cattle.

Lasley et al. (1971) looked at heterosis for short fed and long fed Angus, Charolais and Hereford straightbred and crossbred heifers. Quality grade heterosis for short fed heifers was -1.17% and 1.84% for long fed heifers, both were non-significant. Similiar results were reported by Gaines et al. (1971) using Hereford, Angus and Shorthorn steers and heifers. Crossbred heifers exhibited -1.7% heterosis for quality grade and heterosis for crossbred steers was -4.7%.

When quality grade was adjusted for carcass weight, Long and Gregory (1975b) showed .1% heterosis for Angus, Hereford and Shorthorn cross cattle. However, using Red Poll, Brown Swiss, Hereford and Angus crossbreds, heterosis for quality grade was -3.3% (Gregory et al., 1978e).

There has been little heterosis reported for dressing percent. Most estimates indicate heterosis to be less than 1%. Long and Gregory (1975b) reported .6% heterosis in crossbred Angus and Hereford cattle. Similiar results were reported by Gaines et al. (1971a) and Gregory et al. (1978e). Gaines reported .3% and .7% dressing percentage heterosis for crossbred Angus, Hereford and Shorthorn steers and heifers, while Gregory reported age adjusted heterosis of .8% for Red Poll, Angus, Hereford and Brown Swiss crosses.

Heterosis estimates of percent cutability or the percent yield of boneless closely trimmed cuts, has been near zero (Long, 1980). Long and Gregory (1975b) reported -.1% heterosis in percent cutability in crossbred Angus and Hereford that were adjusted for weight. The heterosis estimate not weight adjusted was .6%. Similiar results were reported by Gregory et al. (1978e). Carcass weight adjusted heterosis estimate was -.35% for Red Poll, Brown Swiss, Hereford and Angus crosses.

Age adjusted estimates have also been reported. Gregory et al. (1966b) reported -.7% age adjusted heterosis for crossbred Angus, Hereford and Shorthorn steers for percent cutability. This is in close agreement with age adjusted heterosis of -.9% from crossbred Red Poll, Hereford, Angus and Brown Swiss cattle reported by Gregory et al. (1978e).

MATERIALS AND METHODS

Data were collected on 425 cows and progeny at the Southeast Kansas Agriculture Experiment Station, Parsons, from 1979 to 1985. Hereford cows present at the station in 1979, were gradually eliminated and replaced with Simmental and Angus straightbred and crossbred cows. A two-breed rotational crossbreeding system was initiated in 1980. Twenty females each will be maintained in a purebred Simmental herd and purebred Angus herd and forty in a two-breed rotational crossbreeding herd. The existing cows were divided into three herds; two were housed at Parsons and one approximately 15 miles southwest at Mound Valley. Average cow weights were 478.38 $\pm$ 37.75 kg for purebred Simmental, 447.54 $\pm$ 46.07 kg for purebred Angus and 457.51 $\pm$ 41.92 kg for the crossbred cows. The cows were pastured primarily on Fescue and Native Grass and supplemented with hay and concentrate when needed during the winter months.

From 1979 to 1983, two herds calved in the fall and one herd had spring born calves. Fall calving cows began calving in late August or early September and continued through November. Spring calves were born in late February through May. Each herd was synchronized and bred AI. Angus, percentage and purebred Simmental bulls were used as cleanup bulls. In 1984, the spring calving herd was eliminated and switched to a fall calving regime. The breeding season lasted 60 to 90 days, dependent on year. Calves were weaned at approximately 205 days of age. Replacement heifers were selected from offspring or bought from producers and steer calves placed in the feedlot or sold. First calf heifers were bred to Angus bulls and subsequentially placed into the rotation. All calves received creep feed except in 1979. In 1979 spring born calves and half of Parsons fall born calves did not receive creep feed.

Data was collected on calving ease, gestation length, birth weight, weaning weight and yearling weight. Steers from 1980 on were placed in the feedlot and carcass data collected. Traits measured include days on feed, average daily gain, final weight, carcass weight, quality grade, yield grade, ribeye area and backfat thickness.

Analysis of Data

All records were used in developing models for birth weight, weaning weight, yearling weight and gestation length (Table 1). SAS General Linear Models (1982) were used in analyzing the data. The statistical model for birth weight was:

$$Y_{ijklmn} = u + H_i + R_j + S_k + D_l + SI_m + E_{ijklmn}$$

where:

Y_{ijklmn} = the birth weight of the n^{th} calf with the k^{th} sex, m^{th} percentage of Simmental, l^{th} age of dam, i^{th} herd and j^{th} year

u = population mean

H_i = the effect of the i^{th} herd

R_j = the effect of the j^{th} year

S_k = effect of the k^{th} sex of the calf

D_l = effect of the l^{th} age of dam

SI_m = effect of the m^{th} percentage of Simmental in the calf

E_{ijklmn} = error term associated with the $ijklmn^{th}$ calf

TABLE 1 : NUMBER OF COW/CALF UNITS BY HERD, YEAR AND BREED USED FOR ANALYSIS OF PRODUCTION TRAITS

	Herd[a]											
	Parsons Spring				Parsons Fall				Mound Valley Fall			
	Hereford	Angus	Simm[b]	Xbred[c]	Hereford	Angus	Simm	Xbred	Hereford	Angus	Simm	Xbred
Year												
1979	33	0	0	0	18	0	0	0	24	0	0	0
1980	28	0	0	0	11	5	0	6	29	0	0	0
1981	27	1	0	0	6	8	0	5	26	0	0	0
1982	8	9	2	4	7	6	2	9	14	0	4	5
1983	5	1	0	3	4	5	3	12	7	9	3	8
1984	0	0	0	0	6	6	5	19	4	9	2	16

[a] Herd location and season of calving is given.

[b] Purebred Simmental cows.

[c] Includes all crossbred cows with Angus, Hereford and Simmental breeding.

The statistical model for gestation length was the same as for birth weight except it did not include sex of the calf.

The statistical model for weaning weight was:

$$Y_{ijklmnop} = u + H_i + R_j + S_k + D_l + SI_m + b_1(A_n - A) + C_o + E_{ijklmnop}$$

where:

$Y_{ijklmnop}$ = the weaning weight of p^{th} calf with the k^{th} sex, m^{th} percentage of Simmental, l^{th} age of dam, n^{th} age of calf and o^{th} creep feed, i^{th} herd and j^{th} year.

u, H_i, R_j, S_k, D_l and SI_m are as defined previously

$b_1(A_n - A)$ = effect of n^{th} age of calf at weaning

C_o = effect of o^{th} creep feed

$E_{ijklmnop}$ = error term associated with the $ijklmnop^{th}$ calf

The statistical model for yearling weight was the same as for weaning weight.

No models were determined for carcass characteristics because data were available from only 40 steer calves.

Heterosis values were calculated using least squares means on actual gestation length, birth weight, weaning weight and yearling weight. Only 82 observations were used in calculating heterosis estimates since all other observations included Hereford blood, and a base a Hereford population was not maintained after 1979 (Table 2). Least squares means were calculated from models presented previously using SAS General Linear Models (1982). The least squares means are presented in Table 3 . Heterosis values for each trait was calculated by subtracting the percentage of Simmental mean from the weighted parental mean divided by the weighted parental mean. Weighted parental means were calculated by multiplying purebred least squares means by the appropriate percentage of Simmental or Angus and adding the two products together. The resulting value was multiplied by 100 to put it on a percentage basis.

Reciprocal cross means were calculated using SAS General Linear Models (1982). Sire and dam breeds were taken into account in calculating least squares means and standard errors for birth weight, weaning weight and yearling weight. Dam breed least squares means were an indication of maternal heterosis.

TABLE 2 : NUMBER OF COW/CALF UNITS BY HERD, YEAR AND BREED USED TO CALCULATE HETEROSIS

	Herd[a]								
	Parsons-Spring			Parsons-Fall			Mound Valley-Fall		
	Angus	Simmental	Crossbred[b]	Angus	Simmental	Crossbred	Angus	Simmental	Crossbred
Year									
1980	0	0	0	5	0	0	0	0	0
1981	1	0	0	7	0	2	0	0	0
1982	9	2	0	4	1	2	0	4	0
1983	1	0	0	5	2	2	9	3	0
1984	0	0	0	6	5	1	9	2	0

a Herd location and season of calving is given.

b Includes only crossbred cows that are composed of Angus and Simmental breeding.

TABLE 3 : LEAST SQUARES MEANS AND STANDARD ERRORS BY TRAIT AND PERCENTAGE OF ANGUS AND SIMMENTAL IN CALF USED TO CALCULATE HETEROSIS VALUES

% breeding of calf			Trait			
Simmental	Angus	No. born	Birth weight (kg)	Gestation length (d)	Weaning weight (kg)	Yearling weight (kg)
0	1	41	31.9 (1.34)[a]	283.9 (2.52)	243.8 (6.99)	305.2 (8.99)
1/8	7/8	2	37.8 (4.65)	293.0 (3.48)	270.7 (16.54)	338.5 (23.31)
1/4	3/4	2	30.9 (4.81)	-	222.0 (18.85)	286.8 (26.71)
1/2	1/2	27	36.3 (1.91)	287.0 (2.69)	256.3 (8.33)	324.0 (12.61)
5/8	3/8	2	39.0 (4.72)	303.7 (4.53)	280.8 (22.54)	364.3 (31.26)
1	0	8	35.1 (2.60)	292.1 (2.07)	244.1 (12.18)	309.8 (16.58)

[a] Standard errors are in parentheses.

RESULTS AND DISCUSSION

Birth Weight

The analysis of variance (AOV) table for birth weight is presented in Table 4. The model explained 37% of the variation in birth weight. All variables in the model except age of dam were significant sources of variation.

The herd a calf was born in appeared to influence birth weight. Calves born in the Parsons spring born herd and the Mound Valley fall calving herd averaged 4.7 kg heavier than the fall calving herd at Parsons (Table 4). McElhenney et al. (1985) reported fall calves were lighter than spring calves at birth. He indicated the heaviest and fastest gaining calves were born in spring, while fall born calves had the lightest birth weights. The difference might be explained by differences in genetic composition in the herds or a higher incidence of leptospirosis in the Parsons fall calving herd which may have caused premature parturitions.

Year of birth also influenced birth weight. As time progressed, birth weight tended to increase by 1.3 kg/yr with the exception of 1983 (Table 4). This is due in large part to the selection pressure for weaning and yearling weight placed on the herds and the eradication of leptospirosis from the herds. Natural service sire calves weighed 1.4 kg more than AI sire calves at birth.

Male calves were 1.8 kg heavier than female calves at birth, and two and three year old cows had calves 1.2 kg lighter at birth than four year and older cows. This agrees with results reported by Pahnish et al. (1969), Gregory et al. (1978b) and McElhenney et al. (1985).

TABLE 4 : ANALYSIS OF VARIANCE, MEANS AND STANDARD ERRORS FOR BIRTH WEIGHT

Source of Variation	DF	Mean Square	Mean (kg)	Std. Error[a]
Herd[b]	2	1559.76**		
Parsons- Spring			35.43[c]	1.10
Parsons- Fall			30.26[d]	0.98
Mound Valley- Fall			34.54[c]	1.05
Year	5	641.18**		
1979			31.31[c]	1.31
1980			32.03[c]	1.21
1981			31.67[c]	1.15
1982			34.59[d]	1.14
1983			32.87[c]	1.13
1984			37.97[e]	1.10
Sex	1	671.85**		
Male			34.33[c]	1.00
Female			32.49[d]	0.99
Age of Dam	3	58.72		
2			32.45[c]	1.15
3			33.21[cd]	1.23
4			34.20[d]	1.15
5-10			33.78[d]	1.06
Simmental in Calves	12	212.33**		
0			31.24[cd]	0.43
0.093			34.47[de]	5.07
0.125			34.15[de]	3.59
0.187			35.25[e]	1.54
0.250			32.01[de]	1.18
0.375			32.08[de]	1.15
0.437			23.21[c]	5.08
0.500			35.73[e]	0.63
0.625			36.16[e]	3.60
0.687			41.34[e]	5.05
0.750			32.57[de]	3.58
0.875			31.37[cde]	5.06
1.000			34.75[de]	1.82
Error	357	54.63		
Total	380			

** $P < .01$

[a] Expressed in kg

[b] Herd location and season of calving is given

[c,d,e] Values with the same source of variation and different superscripts do differ significantly ($P < .05$)

Percentage of Simmental in the calf was also a significant source of variation. Deviations from the linear model should indicate maximum heterosis obtained by specific percentages of Simmental. However, with lack of numbers in certain percentage classes, the results were not conclusive. The trend was to increase deviations up to 50% Simmental and then decrease, although the 50% Simmental class did not show the largest deviation from the expected regression line. Squared deviations ranged from 145.47 kg^2 for the 68.7% Simmental class to .93 kg for the 75% Simmental class.

Gestation Length

The AOV describing gestation length is in Table 5. The gestation length model explained 40% of the total variation found in the trait. Dam age and year variables were significant sources of variation.

1983 had significantly shorter gestation lengths than 1981, 1982 and 1984 born calves. On average, calves were born five days earlier in 1983 than other years (Table 5). 1983 was also the year that produced lighter birth weights. This may indicate that leptospirosis was present in large enough proportions and caused enough premature births to show a decrease in gestation length.

There were little differences in gestation length between calves of varying Simmental percentages. There were 6.8 d ($P > .05$) difference between purebred Angus and Simmental calves, which contradicts work by Gerlaugh et al. (1951).

There were no significant differences among herds (Table 5). This contradicts work done by McElhenny et al. (1985) that indicated fall born calves

TABLE 5 : ANALYSIS OF VARIANCE, MEANS AND STANDARD ERRORS FOR GESTATION LENGTH

Source of Variation	DF	Mean Square	Mean (d)	Std. Error(d)
Herd[a]	2	12.83		
Parsons- Spring			284.36^{b}	1.81
Parsons- Fall			282.13^{b}	1.41
Mound Valley- Fall			283.61^{b}	1.69
Year	3	83.56^{**}		
1981			283.98^{b}	1.57
1982			285.32^{b}	1.69
1983			277.14^{c}	2.31
1984			287.03^{b}	1.87
Age of Dam	3	53.66^{*}		
2			279.93^{b}	1.81
3			283.87^{bc}	2.17
4			283.03^{bc}	2.02
5-10			286.64^{bc}	1.80
% Simmental in Calves	9	10.20		
0			278.90^{bc}	1.90
0.093			279.01^{bcd}	5.99
0.125			283.43^{bcd}	4.24
0.187			281.94^{bcd}	2.67
0.250			275.62^{b}	3.00
0.375			291.12^{d}	5.77
0.437			285.13^{bcd}	5.84
0.500			282.02^{bcd}	1.12
0.625			290.81^{cd}	5.94
1.000			285.71^{bcd}	2.88
Error	102	13.89		
Total	119			

** P< .01

* P< .1

a Herd location and season of calving is given

b,c,d Values with the same source of varation and different superscript do differ significantly (P< .05) have longer gestation lengths than spring born calves. This may be due to the influence of leptospirosis.

Weaning Weight

Sixty-three percent of the variation was explained by the weaning weight model. Table 6 contains the weaning weight AOV table. All variables in the model except dam age were significant sources of variation.

Steer calves were 18.3 kg heavier at weaning than heifer calves (Table 6). This is in agreement with Pahnish et al. (1969) and McElhenney et al (1985). Calves that received creep feed were 31.7 kg heavier at weaning on average than those that were not creep feed. As would be expected, calves from two and three year old dams were 6.4 kg lighter at weaning than from older dams (Table 6).

Fall calves at Parsons were the lightest calves weaned with no differences between spring born calves at Parsons and fall calves at Mound Valley. This again contradicts the work of McElhenney et al. (1985), which indicated spring born calves should be heavier than fall born calves. Age of the calf at weaning was important. With increasing age, weaning weights were 0.74 kg/d heavier.

Purebred and low Simmental percentage calves tended to have lower weaning weights than crossbreds with larger amounts of Simmental breeding present. Five-eights Simmental and 11/16ths Simmental calves had the largest deviations from the expected regression line (Table 6).

TABLE 6 : ANALYSIS OF VARIANCE, MEANS AND STANDARD ERRORS FOR WEANING WEIGHT

Source of Variation	DF	Mean Square	Mean (kg)	Std. Error[a]
Herd[b]	2	2639.10**		
Parsons- Spring			207.00[c]	5.68
Parsons- Fall			195.20[d]	5.36
Mound Valley			209.45[c]	5.54
Year	5	8783.41**		
1979			170.04[c]	6.69
1980			206.99[ef]	6.70
1981			189.38[d]	6.45
1982			203.61[e]	6.36
1983			214.39[f]	6.23
1984			238.88[g]	5.57
Sex	1	13292.59**		
Male			213.02[c]	5.31
Female			194.74[d]	5.19
Age of Dam	3	463.71		
2			193.28[c]	16.29
3			186.32[c]	15.35
4			195.04[c]	19.31
5-10			195.34[c]	14.53
% Simmental in Calves	12	771.44**		
0			201.80[d]	2.68
0.093			186.00[cd]	26.11
0.125			208.78[d]	14.74
0.187			222.55[d]	8.20
0.250			209.45[d]	6.35
0.375			182.53[c]	6.67
0.437			141.62[c]	25.61
0.500			210.39[d]	3.76
0.625			227.65[d]	18.33
0.687			229.58[d]	25.43
0.750			225.88[cd]	17.96
0.875			199.85[cd]	25.43
1.000			199.86[d]	25.43
Age of calf at weaning b = 0.74	1	36578.86**		
Creep fed	1	11046.05**		
Yes			220.58[c]	4.96
No			187.19[d]	6.42
Error	345	11.47		
Total	370			

** $P < .01$

[a] Expressed in kg.
[b] Location of herd and season of calving is given

c,d,e,f,g Values with the same source of variation and different superscript do differ significantly ($P < .05$)

Yearling Weight

The AOV for yearling weight is presented in Table 7. The model accounted for 59% of the total variation. All variables were significant sources of variation in the model.

Herd the calf was born in and year the calf was born again influenced yearling weight. Calves born in the spring and at Mound Valley were 21.1 kg heavier than calves born at Parsons in the fall. Yearling weight has steadily increased by 6.5 kg/yr since initiation of the project, indicating genetic quality of the cattle has increased (Table 7). Yearlings from four year old dams were significantly lighter than other yearlings. Two, three, five year and older dams did not produce calves than were significantly different from one another as yearlings, indicating age of dam did not influence yearling weight.

Age of the calf when yearling weight was taken was most significant. An increase of 1.0 kg in yearling weight per day can be expected for each day older the calf was. Steer calves were 36.4 kg heavier than replacement females as yearlings (Table 7).

As the percentage of Simmental breeding in the calf increased, it appears yearling weight also increased. This would be expected given the frame and growth differences among Angus and Simmental cattle. Deviations from the linear model showed a definate trend to increase up to the 50% Simmental calf and then decrease.

Heterosis

Simmental calves were sired by Abricot, Eagle, Mr. PR, Alpine Polled Proto, Cezon, Bar 5 Fantastic, Formula 10, CPS, Lightning, AR Extra 8J and sons

TABLE 7 : ANALYSIS OF VARIANCE, MEANS AND STANDARD ERRORS FOR YEARLING WEIGHT

Source of Variation	DF	Mean Square	Mean (kg)	Std. Error[a]
Herd[b]	2	14617.04**		
Parsons- Spring			284.21^{c}	9.09
Parsons- Fall			264.79^{d}	8.86
Mound Valley- Fall			287.65^{c}	9.44
Year	4	8212.72**		
1979			193.38^{c}	29.40
1980			290.06^{de}	10.27
1981			298.53^{de}	7.58
1982			305.01^{de}	7.25
1983			309.44^{e}	7.51
Sex	1	134583.74**		
Male			297.01^{d}	8.85
Female			260.70^{c}	8.61
Age of Dam	3	7819.24**		
2			287.17^{c}	10.00
3			287.47^{c}	9.17
4			255.91^{d}	11.44
5-10			284.99^{c}	8.90
% Simmental in Calves	10	4366.18**		
0			271.47^{d}	6.84
0.125			291.32^{d}	21.49
0.187			288.85^{d}	13.67
0.250			267.07^{cd}	15.92
0.375			293.85^{d}	10.92
0.437			210.80^{c}	29.88
0.500			289.75^{d}	7.46
0.625			325.94^{d}	29.84
0.750			305.83^{d}	29.47
0.875			242.89^{d}	29.58
1.00			279.96^{d}	13.74
Age of calf at weaning b = 1.0	1	1690518.28**		
Error	184	1751.24		
Total	205			

** P< .01
* P< .1
[a] Expressed in kg
[b] Location of herd and season of calving is given
[c,d,e] Values with the same source of variation and different superscript differ significantly (P< .05)

of these bulls. The 8 purebred calves composing the basis for comparison had an average gestation length of 292 $\pm$ 2.07 d and birth weight of 35.1 $\pm$ 2.65 kg. Weaning weight average was 244.1 $\pm$ 12.18 kg and 309.8$\pm$ 16.58 kg average for yearling weight.

Forty-one Angus calves sired by PS Power Play, Dalebanks Rito 9144, Dalebanks Barometer 0829, Dalebanks Skymere 9238, Benchmark 0505 Thomas Chaps and Ken Caryl Mr. Angus characterize the purebred Angus population. Average gestation length for purebred Angus was 284 $\pm$ 2.95 d with average birth weight of 31.9 $\pm$ 1.34 kg. Average weaning weight was 243.8 $\pm$ 6.99 kg and 305.2 $\pm$ 8.99 kg for yearling weight.

The crossbred population was sired by bulls used in the purebred Simmental and Angus populations. The results are based primarily on the F_1 generation. Six F_2 calves have been produced thus far in the study. Twenty-six 50% Simmental, 50% Angus calves were born. Of the 26 F_1 calves, 15 were sired by Simmental bulls and 11 calves were sired by Angus bulls. Average gestation length was 287 $\pm$ 2.69 d and birth weight average was 36.3 $\pm$ 1.91 kg for the 50% Angus, 50% Simmental calves. Weaning weight average was 256.3 $\pm$ 8.33 kg and 324.0 $\pm$ 21.61 kg for yearling weight.

Table 8 gives heterosis for birth weight, gestation length, weaning weight and yearling weight by percentage of Simmental breeding in calves produced. The most reliable heterosis values are associated with 50% Angus-50% Simmental calves since most calves in the heterosis analysis were in this group.

Heterosis for birth weight was 8.31%. This is a higher estimate than the average reported value of 4% (Long, 1980). However, Crockett et al. (1978b)

TABLE 8 : PERCENT HETEROSIS FOR BIRTH WEIGHT, WEANING WEIGHT, YEARLING WEIGHT AND GESTATION LENGTH

	Heterosis (%)[a]			
Simmental % in Calf	Birth Wt.	Weaning Wt.	Yearling Wt.	Gestation Length
1/8	16.74 (2)[b]	11.01 (2)	10.72 (2)	2.80 (2)
1/4	-6.12 (2)	-8.95 (2)	-6.36 (2)	-
1/2	8.31 (27)	5.05 (26)	5.39 (13)	-.30 (10)
5/8	14.99 (2)	9.03 (1)	18.26 (1)	5.10 (1)

[a] Heterosis = (Crossbred Avg. - Weighted Purebred Avg./ Weighted Purebred Avg.) * 100. Weighted purebred average = (Angus mean * % Angus in calf) + (Simmental mean * % Simmntal in calf).

[b] Numbers in parentheses indicate number of observations.

reported 7% heterosis for birth weight in two breed rotational crosses in south Florida.

Gestation length heterosis for cows carrying F_1 calves was -.3%. This agrees with the literature that indicates gestation length heterosis is around zero. Gestation length for Simmental cows was significantly longer than for Angus cows. The cows carrying F_1 calves had gestation lengths intermediate in length and did not differ significantly from either parent.

Weaning weight heterosis was calculated as 5.05%. This is in agreement with Long's (1980) reported average of 5%. Many reports of weaning weight heterosis has been reported in the literature. Gerlaugh et al. (1951), using two breed Angus and Hereford crosses, reported 4.8% heterosis. In close agreement with Gerlaugh's results are two reports using two breed Angus, Hereford and Shorthorn crosses. Gregory et al. (1965) and Gaines et al. (1966) both reported 4.7% weaning weight heterosis. MacNeil et al. (1982) using South Dakota Beef Improvement Federation records reported 4.4% heterosis, and Neville et al. (1984) reported 5.1% weaning weight heterosis in two breed crosses using Angus, Polled Hereford and Santa Getrudis cattle.

Heterosis for yearling weight was as 5.39%. This was a slightly larger estimate than reported by Long (1980). Gregory et al. (1966a,b) reported combined yearling weight heterosis of 5.4% for crossbred Angus, Hereford and Shorthorn steers and heifers.

The reciprocal F_1 crosses favor the Angus sired calves raised by Simmental dams. Angus bulls and Simmental dams produced calves 2.16 kg heavier at birth, 32.94 kg heavier at weaning and 23.69 kg heavier at yearling compared to Simmental sired calves raised by Angus dams. Between dam breeds, Simmental cows produced calves 2.16 kg heavier at birth and 15.14 kg heavier at weaning than Angus cows. At yearling, calves fom Simmental dams were 23.69 kg heavier than calves from Angus dams. In the parent populations, purebred Simmental outweighted purebred Angus calves at birth, weaning and yearling. It appears the differences between the reciprocal cross calves can not be totally explained by differences in milk production between the two dam breeds. This indicates the Simmental dam may be able to provide a better maternal environment than the Angus dam.

The basic objective of beef cattle crossbreeding systems is to simultaneously optimize both additive and non-additive gene effects (Gregory and Cundiff, 1980). Studies of rotational crossbreeding systems indicate that high levels of heterosis are sustained in successive generations. F_1 crosses have been produced thus far in the study, which should express maximum individual heterosis. Deviations from the birth weight and yearling weight models indicate the F_1 crosses are expressing large amounts of heterosis. If the deviations for the F_1 calves are not the largest, they are close to being the largest deviations. Since all classes of percentage Angus and Simmental have relatively few numbers, with the exception of 50% Angus-50% Simmental, an extreme in one of those classes could have a significant impact on the deviation.

As foundation of F_1 females are developed and retained in the herds, subsequent generations in the two-breed rotational crossbreeding system should show decreased amounts of heterosis. The second generation females will show decreased individual and maternal heterosis. Normally, F_1 crosses are expected to display near maximum performance, if crossed with a third sire breed (Dickerson, 1969). It has been shown by Dickerson (1969) and Gregory and Cundiff (1980) that after seven generations heterozygosity will stabilize to two-thirds of the sire breed and one-third of the maternal grandsire (Table 9). Thus, heterosis will be two-thirds of the maximum individual and maternal heterosis in this crossbreeding regime. Once equilibrium has been reached, expected individual heretosis for birth weight should be 5.54%, -.2% for gestation length, 3.36% for weaning weight and 3.59% for yearling weight. These estimates are in close agreement with those found in the literature. Because of the fluctuation between genetations in additive genetic composition, breeds used must be generally compatible but still diverse enough to make an impact.

TABLE 9 : GENETIC COMPOSITION AND HETEROSIS EXPECTED IN AN ANGUS-SIMMENTAL ROTATIONAL CROSS[a]

Generation	Sire breed	Additive genetic composition: Dam		Additive genetic composition: Calf		Heterozygosity % relative to F_1	
		Angus	Simm[b]	Angus	Simm[b]	Dam	Calf
		%					
1	Angus	-	100	50	50	0	100
2	Simmental	50	50	25	75	100	50
3	Angus	25	75	63	37	50	75
4	Simmental	63	37	31	69	75	63
5	Angus	31	69	66	34	63	69
6	Simmental	66	34	33	67	69	66
7	Angus	33	67	67	33	66	67
8	Simmental	67	33	33	67	67	67

a Dickerson, 1969. Gregory and Cundiff, 1980.

b Purebred Simmental

CONCLUSIONS

From the results presented, it is evident that the study must be continued if the objectives are to be adequately answered. A solid base of Simmental must be obtained and the Angus base expanded.

Once the rotational crossbreeding program is firmly established and F_1 replacement heifers are selected and bred, the objectives of this experiment will be more completely met. As more numbers are generated, not only will a more complete picture of performance emerge for the percentage Simmental-Angus calves, but heritabilities for gestation length, birth weight, weaning weight and yearling weight can be calculated.

The results thus far for 50% Simmental, 50% Angus calves appear to be in agreement with work previously completed. The heterosis obtained for birth weight, gestation length, weaning weight and yearling weight are in close agreement with previously published work. As the rotational crossbreeding system produces additional generations and individual heterosis is decreased to two-thirds of the maximum obtainable value, the resulting heterosis values will be well in the range of other estimates in all traits using the heterosis values obtained thus far in the study.

Also, it appears there is a significant difference between the two reciprocal crosses. Angus sired calves raised by Simmental dams were significantly heavier at weaning and yearling. The overriding goal of attempting to characterize the performance of the crossbred calves and advising southeast Kansas producers gives this project merit to continue until the objectives are adequately answered.

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HETEROSIS IN SIMMENTAL-ANGUS ROTATIONAL CROSS CALVES

by

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ABSTRACT

Records were collected on 425 cows and progeny at the Southeast Kansas Agriculture Experiment Station, Parsons that were involved in a two breed rotational crossbreeding program since 1980. The rotational crossbreeding system utilized the Angus and Simmental breeds. Statistical models for birth weight, gestation length, weaning weight and yearling weight were elucidated from the collected data. Eighty-two observations were used to calculate heterosis values for birth weight, gestation length, weaning weight and yearling weight. Heterosis values were calculated using least squares means from SAS General Linear Models procedures.

Herd, year of birth, sex and percentage of Simmental were the largest sources of variation in the birth weight model. Age of the calf at weaning was the most important factor in determining weaning and yearling weight models. Herd, year of birth, sex and percentage of Simmental were also important in the weaning and yearling weight models.

Twenty-six F_1 calves were produced in the study in which 15 were Simmental sired and 11 were Angus sired. Average gestation length was 287 $\pm$ 2.69 d for these calves. Average weights for birth weight, weaning weight and yearling weight for these calves were 36.3 $\pm$ 1.91 kg, 256.3 $\pm$ 8.33 kg and 324.0 $\pm$ 21.61 kg, respectively. Calculated heterosis for birth weight was 8.31%, -.3% for gestation length, 5.05% for weaning weight and 5.39% for yearling weight in 50% Angus, 50% Simmental calves. All values were in close agreement with those found in the literature.

F_1 reciprocal cross calves were significantly different. Angus sired calves were 2.16 kg heavier at birth, 32.94 kg heavier at weaning and 23.69 kg heavier at yearling. It appears Simmental dams provide a superior maternal environment for the calves to more adequately express their genetic potentials.