Impact of *Bos indicus* Genetics on the Global Beef Industry[1]

Larry V. Cundiff, R. M. Thallman, and L. A. Kuehn

U.S. Meat Animal Research Center
Agricultural Research Service, U.S. Department of Agriculture[2]
Clay Center, NE 68933-0166

More than half of the cattle in the world are maintained in tropical environments between the tropics of Cancer and Capricorn. The tropic of Cancer is located just south of the tip of Texas and Florida. About 40% of the beef cows in the United States are located in relatively hot and humid subtropics of the Southeast or more arid subtropics of the Southwest. *Bos indicus* germplasm plays a critical role in providing for adaptation of cattle used for beef production in these regions. Experimental results documenting the importance of using both *Bos indicus* and *Bos taurus* breeds in crossbreeding programs or composite populations to exploit heterosis and match genetic potential of cow herds to the climatic environment will be reviewed based primarily on results from the cattle germplasm evaluation (GPE) program at the U.S. Meat Animal Research Center (USMARC), Clay Center, Nebraska conducted in cooperation with experiment stations in the Southern U.S.

GPE Program at the USMARC

Table 1 shows the mating plan for the first eight Cycles of the GPE Program. Each Cycle was an experiment conducted over a time span of about 10 years. In each Cycle, sires of 6 to 11 sire breeds were used to produce F_1 cross calves out of Hereford, Angus, or Composite MARC III (Composite MARC III is ¼ each Angus, Hereford, Pinzgauer, and Red Poll) dams. As a general rule in each Cycle, about 200 progeny per sire breed were produced from artificial insemination (AI) to 20-25 sires per breed. Sires were sampled representing young herd sire prospects (non progeny tested sires) for each breed. Starting with Cycle VII, about half of the sires sampled were chosen from lists of the 50 most widely used bulls in each breed according to registrations. Hereford and Angus sires were used in each Cycle of the program to produce Hereford-Angus crosses to serve as a control group common to each cycle of the program. Some of the Hereford and Angus sires used in each Cycle were repeated in one or more subsequent Cycles to provide ties for pooling of data over Cycles.

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Bos indicus breeds evaluated in the GPE Program have included the Brahman in Cycles I, III and V, Sahiwal (semen imported from Australia) in Cycle III, Nellore (semen from bulls imported into U.S. from Brazil) in Cycle IV, and Boran (semen imported from Australia) in Cycle V. *Bos indicus* influenced American breeds evaluated have included Santa Gertrudis in Cycle II, Brangus in Cycles II and VIII, and Beefmasters in Cycle VIII.

Table 2 summarizes results for weights at birth and weaning for steers and heifers by Brahman, Sahiwal, Pinzgauer, and Tarentaise crosses and Hereford-Angus reciprocal crosses produced in Cycle III of the Program. Corresponding sire breed means for steers are also shown for final weights, feed conversion (Mcal per lb gain), retail product yields and weights, marbling score, and 7-day shear force estimates of tenderness for cooked strip loin steaks in Table 2. Brahman sired progeny were significantly heavier at birth (calved in March-April) and weaning than those by any other sire breed. However, during the 227 day postweaning period which included winter months, gains of *Bos indicus* Brahman and Sahiwal sired steers were lower than those of *Bos taurus* Hereford, Angus, Pinzgauer and Tarentaise sired steers. Even so, Brahman sired steers still produced significantly greater weight of retail product at 447 days of age than any other sire breed because of significantly higher retail product yields. Marbling scores were significantly lower and strip loin steaks were significantly less tender (higher shear force values) for the *Bos indicus* sire breeds than for the *Bos taurus* sire breeds.

Current Breed Differences and Genetic Trends

Results summarized in Table 2 are from steers produced in the mid 1970's. Since that time, breeds have changed significantly, especially if selection has been facilitated by use of expected progeny differences (EPDs) over a long period of time as is the case for weights recorded at weaning and yearling ages. EPDs estimated and reported separately by different breed associations can only be used to compare individual of the same breed. However, since 1992 in the GPE Program, we have used "head to head" comparisons of progeny of sires of different breeds with known current EPDs to estimate across breed expected progeny differences (AB-EPD) factors which can be added to EPDs for different breeds to compare individuals from different breeds (Kuehn and Thallman, 2012). Also, the AB-EPD factors can be added to current breed average EPDs to estimate current breed averages (Table 3). They can also be added to yearly breed averages available from most breeds to estimate and compare genetic trends for different breed's birth weight, weaning weight, yearling weight and maternal milk (Kuehn and Thallman, 2012).

The AB-EPD genetic trends for yearling weight are shown in Figure 1. The AB-EPDs genetic trends show that yearling weights for British Breeds, especially Angus (but also Hereford, Red Angus, and South Devon) are much more comparable to those for Continental European breeds (e.g., Charolais, Simmental, Salers, Gelbvieh, Limousin , Maine Anjou) in recent years than they were in the early 1970's. The slope for the Angus genetic trend is steeper than that for other breeds, reflecting the power of intensive selection and extensive use of artificial insemination over the past 40 years in the Angus breed. The AB-EPDs, reflecting half of the breed difference, indicate that 40 years ago, the breed average yearling weight for Angus was about 120 lb lighter than that for Simmental, but today the average yearling weight for Angus is slightly heavier than Simmental and slightly lighter than Charolais.

The breed means for birth weight, weaning weight, yearling weight, maternal milk, marbling score, rib eye area, and fat thickness shown in Table 3 provide the most accurate estimates of current breed differences available (Kuehn and Thallman, 2012). Estimates of AB-EPD genetic trends (also shown by Kuehn and Thallman, 2012) indicate that breed differences for birth weight have narrowed over the past 40 year. Birth weight increased at a faster rate in British breeds than in continental breeds in the 1970's and 1980's. However, since the early 1990's birth weight genetic trends have flattened out or decreased for most breeds reflecting significant selection intensity for lighter birth weight as a predictor of calving ease. The negative trends have been especially notable in Simmental and Gelbvieh, which included birth weight as a major component of calving ease indexes. In recent years, progeny of Angus and Red Angus sires are still significantly lighter at birth than those of and other sire breed. Consistent with results in the mid 1970's (Table 2), current AB-EPD estimates of breed means (Table 3) indicate that progeny of Brahman sires are still significantly heavier at birth than progeny of any other sire breed (This estimate would be lower or reversed in Brahman influenced dams, as will be discussed later).

For birth year 2010, average weaning weight for Angus sired progeny are about 17 lb lighter than those for Charolais sired progeny and 8 lb lighter than those for Simmental sired progeny (Table 3). For weaning weight, the difference between Angus (or Herefords) and Simmental, or Angus and Charolais, is about 1/3 as great in recent years as it was in the early 1970's. As in cycle III of the GPE Program, Brahman sired progeny have relatively heavy weaning weights but relatively lighter yearling weights (Figure 1) reflecting either inherent differences in growth curves and/or interactions with season at the USMARC (i.e., above average performance during preweaning period spanning summer months and below average gains the postweaning period spanning winter months).

The AB-EPD breed means for Maternal Milk (Table 3) indicate that that Brahman sired crosses excel in Milk production. AB-EPDs genetic trends have remained relatively flat for Brahman and most breeds since the early 1990's, except for Hereford and Angus which have steadily increased, and Simmental and Maine Anjou which have tended to decrease. In the early 1990's, maternal milk AB-EPDs for Simmental sired females were about 22 lb heavier than Angus sired crosses and about 37 lb heavier than Hereford sired females. Today, AB-EPDs for

Maternal Milk are about equal for Simmental and Angus in response to steady selection pressure for reduced maternal milk by Simmental breeders and for increased maternal milk by Angus breeders, a result which raises several questions. Who has their selection objectives right? How much longer should Angus breeders select for higher milk production? Have both Simmental and Angus breeders been correct up to now and achieved an optimum level of milk production needed to support growth rates of their progeny and at the same time maintain relatively high rebreeding conception rates? Answers to these questions depend on interactions between genotype and feed resources available for cow maintenance and production. Research has shown that if feed requirements to support maintenance and milk production are not adequate, postpartum interval increases and rebreeding conception rates decline (e.g., Holloway et al., 1975). Crossing with breeds with relatively low maternal milk AB-EPDs may be more optimal in some environments if feed resources are limited.

Matching Genetic Potential to the Climatic Environment

In choosing breeds to cross for a specific production system it is very important to consider climatic adaptation. In Cycle III of the GPE Program, genotype-environment interaction for reproduction and maternal performance of *Bos indicus X Bos taurus* F_1 cross (Brahman X Hereford, Brahman X Angus, Sahiwal X Hereford, Sahiwal X Angus) and *Bos taurus X Bos taurus* F_1 cross (Hereford X Angus, Angus X Hereford, Pinzgauer X Hereford, and Pinzgauer X Angus) females in a temperate (Nebraska) and subtropical (Florida) environment. About 1/3 of the F_1 females of each breed group produced at the USMARC were transferred at about 8 months of age to the Subtropical Agricultural Research Station (STARS, ARS-USDA) at Brooksville, Florida. The other 2/3 of the females remained at the USMARC. The females were maintained under standard management practices at each location. Females at both locations were pasture mated to Red Poll bulls produced at the USMARC for their first calving and to Simmental bulls produced at the USMARC calves for subsequent calvings through 6 years of age. Key results from this experiment for birth weight of calves, unassisted calving rate and weaning weight per cow exposed to breeding are summarized in Figure 2.

The genotype-environment interaction was highly significant for both calving ease and birth weight. Calving ease (unassisted calving rate) was significantly greater in Florida than in Nebraska, especially for *Bos taurus X Bos taurus* cross females. The increased assistance in Nebraska was primarily associated with heavier birth weight (17.5 lb over all breed groups) of calves produced in Nebraska. Most of the advantage in calving ease was observed in first calvings. Birth weight of calves produced by *Bos indicus X Bos taurus* cross females were significantly lighter than those produced by *Bos taurus X Bos taurus* cross females, especially in Nebraska. This result comparing Brahman and Sahiwal as sires of dams to Hereford, Angus, or other *Bos taurus* sire breeds (Figure 2), is just the opposite to those comparing Brahman and

Sahiwal as sires of calves to *Bos taurus* breeds (Tables 2 and 3). Brahman and Sahiwal sired calves out of Hereford and Angus dams were significantly heavier at birth than Hereford-Angus reciprocal crosses (Table 2), but maternal birth weights of calves produced by *Bos indicus X Bos taurus* dams were significantly lighter than *Bos taurus X Bos taurus* cross dams (Figure 5). *Bos indicus X Bos taurus* cross females have a remarkable ability to limit prenatal growth of their offspring (Figure 2) and to excel in calving ease. This favorable maternal effect was especially pronounced in Nebraska.

The genotype-environment interaction was highly significant for weaning weight per cow exposed (Figure 2). Weaning weight per cow exposed combines the most important output components of cow herd production efficiency (reproduction rate, survival rate, and progeny growth rate) into one trait. Weaning weight per cow exposed was significantly greater for *Bos indicus X Bos taurus* cross dams than for *Bos taurus X Bos taurus* cross dams, especially in Florida (28%), but also in Nebraska (5.8%).

Cold Tolerance and Beef Tenderness

The calves produced by *Bos indicus X Bos taurus* females by Red Poll or Simmental sires had 75% *Bos taurus* and 25% *Bos indicus*, while those produced by the *Bos taurus X Bos taurus* dams by the same Red Poll and Simmental sires had 100% *Bos taurus* inheritance. These results favoring *Bos indicus X Bos taurus* cross cows, even in Nebraska, prompted us to ask, what is the optimum proportion *Bos indicus* inheritance in the temperate region of Nebraska? To address this question, the *Bos indicus X Bos taurus* F_1 cross (Brahman X Hereford, Brahman X Angus, Sahiwal X Hereford, Sahiwal X Angus) and *Bos taurus X Bos taurus* F_1 cross (Hereford X Angus, Angus X Hereford, Pinzgauer X Hereford, and Pinzgauer X Angus) females were mated to produce reciprocal backcross (purebred Angus, Hereford, Brahman, and Pinzgauer sires used to produce F_1 cross females) and F_2 (F_1 bulls mated to F_1 females) progeny to evaluate alternative ratios of *Bos indicus* to *Bos taurus* inheritance. These matings were made only in Nebraska, because similar breed groups had been evaluated at other experiment stations in Florida and the Southern region of the U.S.

Results from this experiment for mortality of calves born in the spring (late February to early May) are summarized in Table 4. Mortality increased significantly as the proportion *Bos indicus* inheritance increased and as average temperature (around the clock mean 24 hr temperature) on the day of birth decreased. Mortality of 100% *Bos taurus* (0:100) was not different from that for 25% *Bos indicus* (25:75) calves, even on the coldest days. These results for mortality were observed under our standard management protocol in which any calves showing signs of cold stress (increased shivering, glazed eyes, huddling, and decreased activity) were revived by placing them in a heat chamber (100 to 120 degrees Fahrenheit) for a span of time (30 minutes to 3 hours). Results from this study revealed that calves with 50% or more *Bos indicus* inheritance were not as well adapted as calves with 25% or less *Bos indicus* inheritance to calving conditions which can be characterized as cold (mean 24 hr temperature ^{O}F or less), cold and wet (46^{O}F or less combined with 0.1 inch precipitation or more), or cold and windy (when a measure of heat loss, Ko > 800 Kcal/m^2/hour; Sipple and Passel, 1945). Results for heat chamber usage and for the combination of heat chamber usage and mortality (assuming many if not all calves would have died had they not been revived in the heat chamber) indicated losses would have been severe for calves with 50% *Bos indicus* inheritance and especially severe for calves with 75% *Bos indicus* inheritance without the use of the chamber.

We also studied effects of season and proportion *Bos indicus* inheritance on average daily gains of steer (males castrated within 24 hr of birth) calves from birth to slaughter at about 15 months of age (Sousa et al, 1993). Breed effects for average daily gain, analyzed separately for different seasons classified by month (03-07 denotes March - July, 08-09 denotes August – September, etc,) are shown in Figure 6. Breed effects shown in Figure 3, estimated by regressing average daily gain on breed composition expressed as a proportion (i.e., 0. .25, .5, or .75), shown in Figure 6 represent the deviation of each breed from Angus, (e.g., 100% Brahman versus 100% Angus). Estimates show higher average daily gain for Brahman than Angus sired steers during spring and summer months for both pre-weaning (March – July) and post-weaning (June -August) periods, but significantly lower post-weaning average daily gains during winter periods (November - December, January – February, March – April). In general, *Bos indicus* breeds performed relatively well in summer months but poorly in winter months.

Effects of 0, 25, 50 and 75% *Bos indicus* inheritance on shear force estimates of tenderness are shown in Figure 4. Shear force required to slice through half inch cores of cooked rib steaks increased 1.6 lb for each 25% increase in Brahman inheritance and 2.9 lb for each 25% increase in Sahiwal inheritance (Crouse et al., 1989). Similar results were observed in sensory panel estimates of tenderness.

Cow Efficiency

Biological efficiency differences in *Bos indicus X Bos taurus* and *Bos taurus X Bos taurus* cross cows were evaluated using the Hereford-Angus reciprocal cross and F_1 Pinzgauer, Brahman, Sahiwal cross cows produced in Cycle III of the program. The cows were 11 and 12 years of age raising Charolais sired calves born during late March of early April. Cows and calves were moved to the feed lot approximately 40 days after calving and were assigned to replicate pens (3 pens per breed group) with 12 pairs per pen. Cows were fed to maintain their initial weight commencing at about 50 days postpartum. Cow and calves were weighed bi-weekly. If average pen cow weight was reduced below initial weight, feed was increased to bring average pen cow weight up to the initial weight (or vice versa, if average weight was increased above initial weight, feed was decreased to bring average weight down to initial weight) bi-weekly for the 126 day test. Output/input differences among the breed groups are shown in Table 5. Performance of each breed cross group is presented as a ratio relative to the overall mean. Weight gains, recorded during summer months, were significantly greater than those for any other breed group. Calf creep consumption was inversely related to levels of milk production, with the exception of Pinzgauer crosses. Differences among F_1 cross groups were highly significant (P<.01) for cow size, milk yield, and level of fatness. Brahman cross cows were the largest and produced the highest daily milk yield. Sahiwal cross females were similar to Brahman cross females in milk yield and level of fatness but were significantly smaller in mature weight. Pinzgauer cross cows were intermediate in milk yield and mature weight and were similar to Hereford-Angus crosses in level of fatness. Hereford-Angus crosses were the lightest in mature weight and produced the lowest amount of milk per day. When outputs and inputs were combined into an estimate of efficiency, progeny gain, lb / Mcal metabolizable energy intake by cow and calf, Brahman and Sahiwal cross cows were approximately 10% more efficient than Hereford-Angus or Pinzgauer crosses. At the conclusion of this experiment, the condition of teeth in the cows remaining in the experiment was examined. Frequency of normal, broken, loose, and missing incisors were assessed. Frequency of normal teeth was much greater in Brahman and Sahiwal crosses than in Hereford-Angus and Pinzgauer cross cows. Frequency of missing incisors was greater in *Bos taurus X Bos taurus* crosses than in the *Bos indicus X Bos indicus* crosses. Superior longevity *of Bos indicus X Bos taurus* crosses has been well documented (e.g., Thrift and Thrift, 2003).

These results favoring efficiency of *Bos indicus* cross cows are similar to those from a subsequent experiment involving mature F_1 cross Hereford, Angus, Brahman, Boran, and Tuli cows sampled from Cycle V of the GPE Program (Jenkins and Ferrell, 2004). These cows were individually fed during lactation while nursing Charolais sired calves (Jenkins and Ferrell, 2004). Efficiency was defined as the ratio of age adjusted preweaning weight gain per unit total dry matter intake of the cow during the preweaning period. B*os indicus* Brahman (88.6 g/kg DMI; i.e., g 212-day calf wt/kg DMI of dam from birth to weaning) and Boran (85.0 g/kg DMI) sired cows did not differ in efficiency but were significantly more efficient than *Bos taurus* tropically adapted Tuli (74.2 g/kg DMI) and Hereford-Angus (72.6 g/kg DMI) crosses. Results from these trials contrast to results from another trial in which Hereford-Angus cross cows were about equal in cow efficiency to Red Poll, and Maine Anjou crosses and significantly more efficient than higher milking Braunvieh or Gelbvieh crosses or larger size Chianina crosses (Jenkins et al., 1991).

Additional Tropically Adapted Breeds Characterized in the GPE Program

In Cycle V of the Germplasm Evaluation Program at MARC (Tables 6 and 7), tropically adapted Tuli, Boran and Brahman sire breeds were evaluated relative to Hereford and Angus crosses

(Cundiff et al., 2000). The Tuli, a Sanga type of cattle (non-humped), originates from Africa. Semen from nine Tuli bulls used was imported from Australia. Tuli were introduced into Australia from Zimbabwe in 1990 by embryo transfer. Borans are a pure Zebu breed (*Bos indicus*, humped) that evolved in southern Ethiopia and are believed to have been developed for milk and meat production under stressful tropical conditions. Boran cattle were also introduced into Australia from East Africa (Zambia) in 1990. Semen from eight Boran bulls used was imported from Australia.

Estimates of sire breed means averaged over Angus and Hereford dams are shown in Table 6 for preweaning traits and Table 7 for final weight, feed conversion, and carcass and meat traits of steers. Least significant differences (LSD$\leq$.05) are also shown for each trait as a guide to statistical significance of differences between breed groups. Breed group differences equal to or greater than the LSD$\leq$.05 are expected to result by chance only 5% of the time if a large number of experiments were conducted replicating the present experiment. Performance of Nellore crosses, also shown in Tables 6 and 7, were estimated by adding the deviation of Nellore crosses from Hereford and Angus crosses produced in Cycle IV (Wheeler et al., 1996; Wheeler et al., 1997; Cundiff et al., 1998) to the mean of Hereford and Angus crosses produced in Cycle V. The least significant differences (P$\leq$.05) between Nellore crosses and other breeds can be approximated by multiplying 1.5 times the least significant difference shown in Tables 6 and 7 for Cycle V contrasts.

Results indicate that Tuli cattle produce crossbred progeny with carcass and meat characteristics more similar to progeny sired by British *Bos taurus* breeds (i.e., Hereford and Angus) than to progeny sired by *Bos indicus* breeds (i.e., Brahman or Boran) (Table 6). However, Tuli crosses had relatively low average daily gains. Performance of Nellore crosses was comparable to that of current Brahman crosses for preweaning and postweaning growth rate, weight and percentage of retail product. Tuli and Boran crosses were significantly younger at puberty and had higher percentages of calf crop weaned as 2-year-olds than Brahman crosses (Table 7). However, at 3 years of age or older, percentages of calf crop weaned did not differ among Nellore, Brahman, Boran and Tuli sired females. At all ages, maternal weaning weight (200 day weight per calf) was greater for Nellore and Brahman than Boran sired F_1 cross females which were in turn greater than Tuli sired F_1 cross females.

In Cycle VIII of the GPE Program Brangus, Beefmaster, Bonsmara, and Romosinuano were evaluated relative to Hereford and Angus crosses (Table 8). The Bonsmara is a composite breed developed in South Africa with 50% Africander (an African Sanga breed), 25% Hereford, and 25% Shorthorn inheritance. Semen was used from 19 Bonsmara bulls, was purchased from Mr. George Chapman, Amarillo, TX who imported Bonsmara into the U.S. The Romosinuano breed was developed primarily in Colombia and introduced into the U.S. from Venezuela at the Subtropical Agricultural Research Station (STARS), ARS, USDA and the University of Florida, Brooksville, FL. The Romosinuano is a Criollo (domestic) breed of Central America that traces back to *Bos taurus* cattle introduced from Europe about 400 to 500 years ago. Semen from 20 Romosinuano bulls was used.

Estimates of sire breed means averaged over Angus and MARC III dams and LSD$\leq$.05 are shown in Table 8 for preweaning traits and Table 9 for final weight, feed conversion, and carcass and meat traits of steers. Beefmaster sired calves were heavier at birth than Herefords, Brangus and Bonsmara. Romosinauano and Angus were lightest at birth. Romosinuano had lower calving difficulty scores than any other breed. Beefmaster were heavier at weaning than any other breed. Brangus ranked second for weaning weight, but did not differ significantly from Angus. Hereford and Bonsmara were similar in weaning weight and significantly heavier than Romosinuano.

Beefmaster sired steers had significantly heavier final weights than all other breeds except Angus (Table 9). Angus, Brangus, and Hereford significantly heavier than Bonsmara sired steers at 426 days, which were in turn significantly heavier than Romosinuano sired steers. Romosinuano and Bonsmara sired steer carcasses had significantly higher percentages of retail product than Brangus, Hereford, Beefmaster and Angus sired steer carcasses. Estimates of weight of totally trimmed boneless retail product at 426 days of age were very similar for Beefmaster and Brangus sired steer carcasses and were significantly greater than estimates for Angus and Hereford.

Marbling score and percentage grading USDA Choice or higher were significantly greater for Angus than for any other sire breed. Hereford sired steers ranked second and had significantly greater marbling scores and a greater percentage grading USDA Choice or higher than those from Romosinuano, Bonsmara and Beefmaster sired steers. Brangus ranked third in marbling and percentage grading USDA Choice or higher, but did not differ significantly from Hereford or from Romosinuano, Bonsmara, or Beefmaster.

Reproduction and maternal performance of the F1 females produced in Cycle VIII was evaluated in two environments: a temperate environment represented by U.S. Meat Animal Research Center (USMARC) at Clay Center, Nebraska and a subtropical environment represented by Louisiana State University (LSU) at Baton Rouge, Louisiana (Cundiff and Franke, 2006; Franke and Cundiff, 2006). At about 8 months of age, the females were divided into two groups with half (202 head) transferred by truck to LSU and half (202) remaining at the USMARC. Management of F1 females and their progeny was consistent with that generally practiced under commercial production systems in the respective regions. Sire breed X location interaction was not significant for 400 day weight of females. Beefmaster (849 lb) did not differ significantly from Brangus (826 lb) or Bonsmara (811 lb) for 400-day weight. Bonsmara sired females had greater 400-day weights than Romosinuano (745 lb) sired females. Even though average daily gain was significantly less in Louisiana than in Nebraska, age at puberty was significantly younger (14 days) for females in Louisiana than in Nebraska, possibly due to stresses associated with transfer or possibly effects of longer exposure to daylight in Louisiana than Nebraska on age at puberty (Table 10). Differences among sire breeds and sire breed X location interaction were not significant for age at puberty. Weight at puberty was 38 kg lighter in Louisiana than Nebraska.

For 2-year-old heifers, sire breed of female X location was significant for calving ease score, percentage unassisted births and 205-day weaning weight. Heifer sire breed differences were significant for calf birth and 205-day weight (Table 10). Birth weights for calves born in Nebraska were 4.0 lb heavier than for calves born in Louisiana. Birth weights of calves for Brangus (76.9 lb), Beefmaster (76.0 lb), and Bonsmara (75.0) sired females were similar and greater than those for Romosinuano (71.4 lb) sired females. The percentage of unassisted births was greater in Louisiana (97%) than Nebraska (77%), especially for Brangus, Beefmaster, and Bonsmara sired females, however Romosinuano sired females had similarly low percentages of unassisted births in both locations. For 205-d weight, the difference between locations was similar for Brangus and Beefmaster sired females and of nearly twice the magnitude of that for Bonsmara and Romosinuano sired females (Table 10). Heifers retained in Nebraska had a 9.8% higher weaning rate than heifers transferred to Louisiana.

Sire breed means in Louisiana and Nebraska for cows calving at 3 – 7 years of age are shown in Table 11 for calf crop weaned percentage, and 205-day weaning weight per calf and 205-day weaning weight per cow exposed to breeding. Effects of Sire breed, Location, and Sire breed X Location interactions were not significant for calf crop percentage. Calf crop percentages were similar for all sire breeds in both Louisiana (averaging 85.2%) and Nebraska (averaging 87.6). However, effects of Sire breed, Location, and Sire breed X Location were all highly significant ($P<.01$) for maternal 205-day weaning weight. In Louisiana, maternal weaning weights did not differ significantly for the four sire breeds, and Romosinuano ranked second to Beefmaster, and slightly higher than Bonsmara (3rd) and Brangus (4th). Rankings for maternal weaning weights were different in Nebraska where Angus (2nd) and Herefords (4th) were also included, with Beefmaster (1st), Brangus (3rd), and Bonsmara (5th) and Romosinuano (6th). In Nebraska, maternal 205-day weaning weights were significantly greater for Beefmasters than for Herefords, Bonsmara and Romosinuano. Brangus, Herefords and Bonsmara did not differ significantly for maternal weaning weight, but all three weaned significantly heavier calves than Romosinuano sired females. The relatively better performance of Romosinuano in Louisiana than in Nebraska indicates that they are more adapted to the subtropics of the Gulf Coast than to the temperate region of the Northern great plains.

Results from a number of experiments conducted by Experiment Stations cooperating in Southern Regional Project S-243 and S-277 have been conducted characterizing tropically adapted *Bos taurus* breeds (e.g., e, Tuli, Romosinuano) relative to *Bos ind*icus or *Bos taurus* breed(Southern Cooperative Series Bulletin. 405). Results from these experiments indicate that these breeds can reduce age at puberty, and improve tenderness of beef in tropically adapted composite populations, provided they are crossed with other *Bos indicus* or *Bos taurus* to optimize size and provide for high levels of heterosis.

Biological Types

Results from the Germplasm Evaluation Program at MARC have provided a basis for classifying breeds into biological types (Table 12). In the table increasing X's (lower case x's denote intermediate levels) indicate relatively greater growth rate and mature size, lean to fat ratios, marbling, beef tenderness, age at puberty of females, milk production, and tropical adaptation. However, biological type classifications today, are not necessarily the same as they were 30 to 40 years ago, especially for traits such as growth rate, mature size and milk production. In the 1970's, Continental-European breeds had significantly faster growth rates and heavier body weight at weaning, yearling and mature ages. Recent results indicate that British breeds are comparable to Continental-European breeds for these traits (e.g., Yearling weight, Figure 1). As noted above, average differences among breeds have narrowed considerably for yearling weight (Figure 1) and maternal milk (Table 3). These changes are reflected in current biological type classifications shown in Table 12.

EPDs for carcass traits were gradually introduced by a few breeds about 15 years. Only recently, after ultrasound estimates became available, have EPDs for carcass traits been available for a significant number of animals in most breeds (see Table 3). Thus, differences among breeds for carcass traits are about the same today as they were in the 1970's. Continental-European breeds and *Bos indicus* breeds still have higher retail product yields than British breeds; however, British breeds, especially Angus, Red Angus, and Shorthorn's still excel in marbling relative to Continental-European breeds. Genetic potential for retail product and marbling are more nearly optimized in cattle with 50:50 ratios than in cattle with higher or lower ratios of Continental-European to British inheritance.

Heterosis

Heterosis is by definition the difference between the mean for reciprocal F_1 crosses and the mean for parental purebreds contributing to the cross. Experiments conducted at many experiment stations (Iowa, Indiana, Missouri, Ohio, Virginia, and the USMARC) have shown that effects of heterosis increase production per cow about 20 to 25 percent in *Bos taurus* breed crosses (Cundiff et al., 1974, Gregory and Cundiff, 1980). Experiments involving *Bos indicus X Bos taurus* crosses (e.g., Florida, Louisiana, Texas, USDA and Florida) have shown that effects of heterosis are much larger *in Bos indicus X Bos taurus* crosses than in *Bos taurus X Bos taurus* crosses for most traits and increase production per cow at least 50 percent (Cartwright et al., 1964; Cundiff, 1970).

Experimental results indicate that dominant genes are primarily responsible for heterosis (e.g., black coat color is dominant to that for red coat color, etc). Genes occur in pairs, with one copy inherited from the sire and the dam. With dominant gene action, one copy of a gene tends to be sufficient for an animal to cope with a specific stress. Forces of natural selection have favored dominant genes with favorable effects on adaptation or performance. Any dominant gene with an unfavorable effect, was easily observed and purged or at least reduced to very low frequencies in animal populations by forces of selection (natural or man directed). Hence, F1 crosses tend to possess the maximum number of favorable genes capable of coping with stress more effectively than either parent breed. This phenomenon is particularly evident in crosses of *Bos indicus* breeds which evolved in the tropical environments, and *Bos taurus* breeds which evolved in temperate environments. The F1 crosses are capable of performing relatively well in either a tropical or temperate environment, but they perform especially well in an intermediate subtropical environment, intermediate that is to the more harsh tropics where *Bos indicus* breeds evolved and to temperate environments where *Bos taurus* breeds evolved. Results have shown that heterosis is maintained a relatively high levels at least proportional to expected heterozygosity in rotational crosses (Gregory and Cundiff, 1980) and in composite populations (Gregory et al., 1999). For any specific number of breeds, rotational systems of crossbreeding provide for more effective use of heterosis than composite populations. However, uniformity of cattle and greater consistency of end product can be provided for with greater precision by use of composite populations than by use of rotational crossing of pure breeds.

Implications

It is very important to match genetic potential in cow herds to with the climatic environment. To limit costs of production and improve efficiency of beef production, in the harshest tropics of the world, possibly 100% or at least 75% *Bos indicus* germplasm may be optimal. Perhaps some influence of tropically adapted *Bos taurus* germplasm (e.g., Romosinuano, Senepol, Tuli, Africander, etc.) can be included in harsh tropical regions to exploit heterosis, reduce age at puberty, and improve beef tenderness.

In hot and humid subtropical regions such as the U.S. Gulf Coast (see Figure 2), and much of Brazil, and Australia, cattle with 50:50 ratios of *Bos indicus* to *Bos taurus* inheritance are more optimal. Use of Brahman, Nellore, or Boran F_1 cross cows or rotational crossing of composite breeds such as Beefmaster, Brangus, Bonsmara, or Santa Gertrudis appear to be especially appropriate in subtropical environments.

A little further north in subtropical region of the U.S. (e.g., climatic zones in Figure 2, including much of Texas, Southeastern Oklahoma, central Arkansas, Tennessee and parts of North Carolina or South in Brazil and Northern Argentina, and Central Australia), 25:75 ratios of *Bos indicus*:*Bos taurus* inheritance appears to be more optimal in cow herds.

Further north in temperate climates of North America, crosses with 100% *Bos taurus* inheritance are more optimal to provide for greater calf survival during cold or cold and wet calving conditions, greater feed efficiency during winter months, carcasses with higher USDA Quality grades, and greater beef tenderness.

Bos indicus X Bos taurus crosses excel in cow efficiency, productivity and longevity. However, even in subtropical regions, these advantages are tempered by older age at puberty, and reduced meat tenderness. Systematic crossbreeding programs can be used to manage these trade-offs. If replacement requirements for suitably adapted females are met and terminal crossing is feasible, then a *Bos taurus* breed can be used to optimize carcass and meat characteristics and increase market value of terminal cross slaughter progeny. To optimize quality grade and yield grade of slaughter progeny, it may be advisable to terminally cross to hybrid or composite bulls with 50:50 ratios of Continental to British breed inheritance. Angus has traditionally been considered a maternal or general purpose breed for use crossbreeding programs in commercial herds. However, in recent years the Angus breed has positioned itself to be considered for terminally crossing in view of relatively high growth rate and carcass value, especially for production of slaughter progeny targeting markets paying a premium for highly marbled beef. Even on crossbred cows with as much as 50% Angus inheritance, Angus can be used. However, it is advisable that all females with 75% or more Angus inheritance be managed and fed for slaughter, and not be retained as cow herd replacements. This is important to maintain highly significant benefits of maternal heterosis on cow productivity and longevity which are more than twice as great as benefits of individual heterosis on pre- and postweaning traits and carcass traits of progeny. If Angus bulls are used for terminally crossing, it would be helpful to select bulls with lower EPDs for backfat thickness to improve yield grades and retail product yield or slaughter progeny.

Registrations in breed associations (Table 13) can be used to approximate the flow of germplasm from the seedstock industry to commercial production in the U.S. Registrations for American breeds (Brahman, Santa Gertrudis, Brangus, and Beefmaster) peaked in the mid-1980's and has decreased significantly to lower than optimal levels since that time. About 40% of the beef cows in the U.S. are maintained in subtropical regions of the U.S. (Figure 2). To optimize the influence of tropically adapted breeds, it is estimated that about 12 to 15% of the seedstock used in commercial beef production should originate from breeds adapted to tropical or subtropical environments.

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TABLE 1. SIRE BREEDS USED TO PRODUCE F_1 CROSSES WITH ANGUS AND HEREFORD DAMS IN THE GERMPLASM EVALUATION PROGRAM AT MARC[a]

Cycle I[b] 70-72	Cycle II[c] 73-74	Cycle III 75-76	Cycle IV 86-90	Cycle V 92-94	Cycle VI 97-98	Cycle VII 99-00	Cycle VIII 01-02
Hereford	Hereford	Hereford	Hereford	Hereford	Hereford	Hereford	Hereford
Angus	Angus	Angus	Angus	Angus	Angus	Angus	Angus
Jersey	Red Poll	Brahman	Longhorn	Tuli	Wagyu	Red Angus	Beefmaster
S. Devon	Braunvieh	Sahiwal	Salers	Boran	Norweg. Red	Limousin	Brangus
Limousin	Gelbvieh	Pinzgauer	Galloway	Belg. Blue	Sw. Red&Wh.	Charolais	Bonsmara
Simmental	Maine Anj.	Tarentaise	Nellore	Brahman	Friesian	Simmental	Romosinuano
Charolais	Chianina		Shorthorn	Piedmontese		Gelbvieh	
			Piedmontese				
			Charolais				
			Gelbvieh				
			Pinzgauer				

a Sire breeds mated to Angus and Hereford females, Composite MARC III (1/4 Angus, Hereford, Red Poll and Pinzgauer) cows were also included in Cycles V, VI, and VII.

b In Cycle I Hereford, Angus, Brahman, Devon, and Holstein sired progeny were evaluated as 3-way crosses out of Cycle I F_1 cross females when calving as 2-year-olds.

c In Cycle II Hereford, Angus, Brangus and Santa Gertrudis sired progeny were evaluated as 3-way crosses out of Cycle II F_1 cross females when calving as 2-year-olds.

TABLE 2. BREED GROUP MEANS FOR WEIGHTS, FEED CONVERSION AND CARCASS TRAITS OF F1 STEERS PRODUCED IN CYCLE III OF THE GPE PROGRAM (447 d)

Breed Group	Birth wt[a] lb	200 d wn wt[a] lb	Final wt[b] lb	Mcal per lb gain[b]	Retail product[c] %	Retail product[c] lb	Marbling[c] sc	7-d Shear[c] lb
HA and AH	78.0	448	1030	9.58	65.8	430	9.8	7.6
Brahman-X	89.5	474	1044	9.95	68.9	468	8.8	8.6
Sahiwal-X	83.1	450	972	10.15	68.6	431	9.3	9.4
Pinzgauer-X	85.8	456	1034	9.59	68.9	445	11.5	7.7
Tarentaise-X	82.0	461	1026	9.93	69.3	454	11.1	8.6
LSD≤.05[d]	1.3	12	32	.25	1.0	18	.9	.3

[a] Gregory et al., 1979; [b] Cundiff et al., 1984; [c] Koch et al., 1982

[d] Breed group differences equal to greater than the least significant difference (LSD≤.05) are expected to result by chance only 5% of the time if a large number of experiments were conducted replicating the present study.

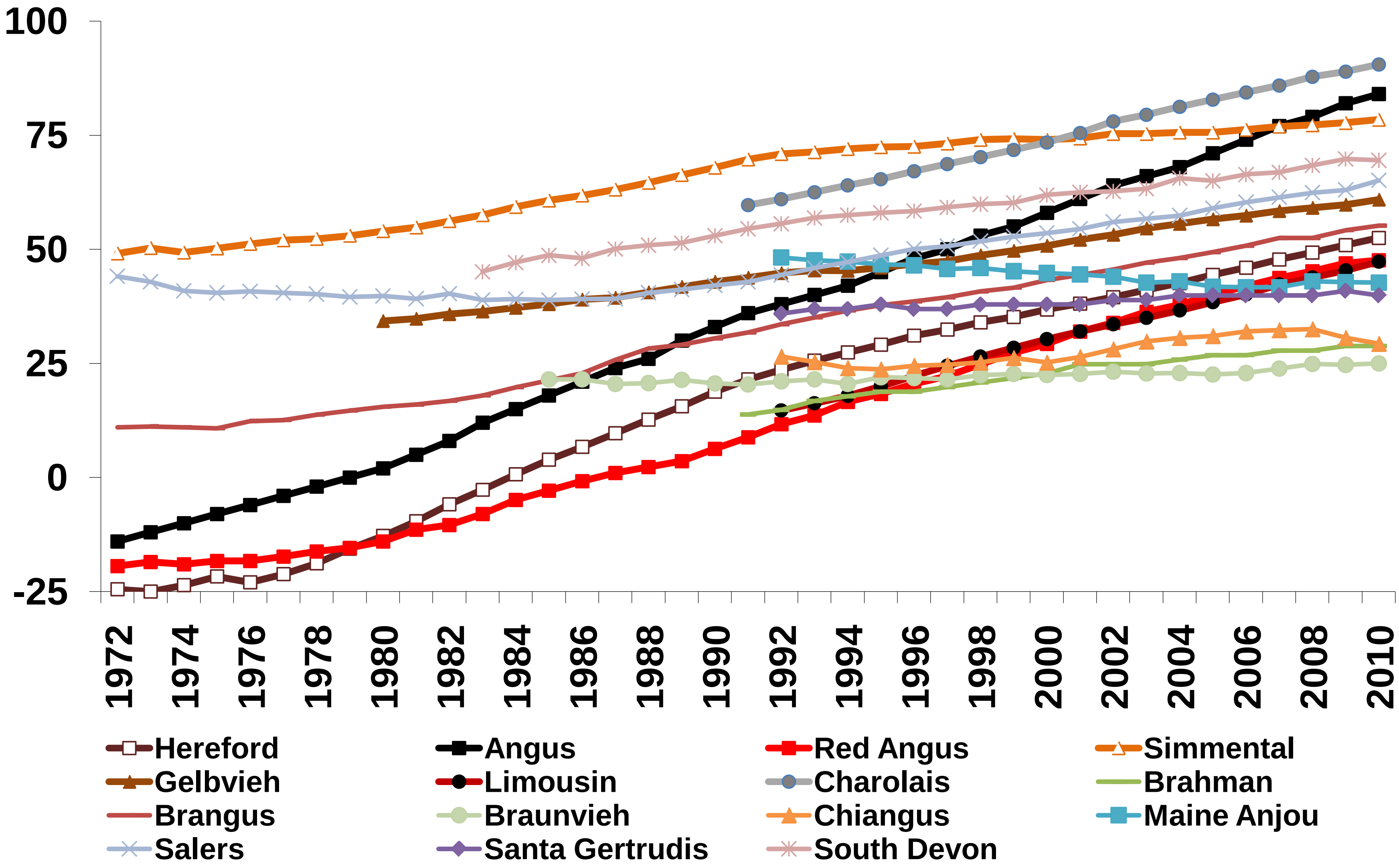

Figure 1. Genetic Trends for Yearling weight AB-EPDs (lb). (Kuehn and Thallman, 2012)

Table 3. AB-EPD Breed Means for Birth Year 2010 (Kuehn and Thallman, 2012)

Breed	Birth wt lb	Weaning wt lb	Yearling wt lb	Maternal milk lb	Marbling score[a]	Rib eye area sq. in.	Fat thick. in
Angus	89.8	582.0	1036.8	570.2	5.92	12.96	0.587
Hereford	94.3	576.2	1004.6	548.5	5.19	12.77	0.526
Red Angus	90.3	566.3	999.4	562.5	5.59	12.60	0.544
Shorthorn	96.3	565.7	1015.6	568.3	5.34	12.86	0.418
S. Devon	94.8	578.7	1021.3	568.8	5.84	12.99	0.477
Beefmaster	95.0	578.3	997.3	558.0			
Brahman	100.8	592.2	980.0	576.9			
Brangus	92.4	571.0	1006.9	565.8			
Santa Gertrudis	96.0	577.7	992.7		4.82	12.46	0.463
Braunvieh	92.1	556.7	976.7	582.3	5.23	13.59	0.391
Charolais	97.2	599.3	1041.2	560.7	5.05	13.76	0.356
Chiangus	93.2	556.9	989.1		5.32	13.06	0.445
Gelbvieh	93.3	580.8	1012.7	578.5			
Limousin	93.3	579.5	1000.0	559.1	4.75	14.24	
Maine Anjou	93.8	561.4	995.3	563.2	4.92	13.67	0.371
Salers	91.6	573.2	1016.8	570.7	5.58	13.40	0.368
Simmental	93.9	590.7	1030.5	571.4	5.11	13.75	0.375
Tarentaise	91.6	584.1	1001.6	572.2			

[a] Marbling score units: 4.00 = Sl^{00} ; 5.00 = Sm^{00}

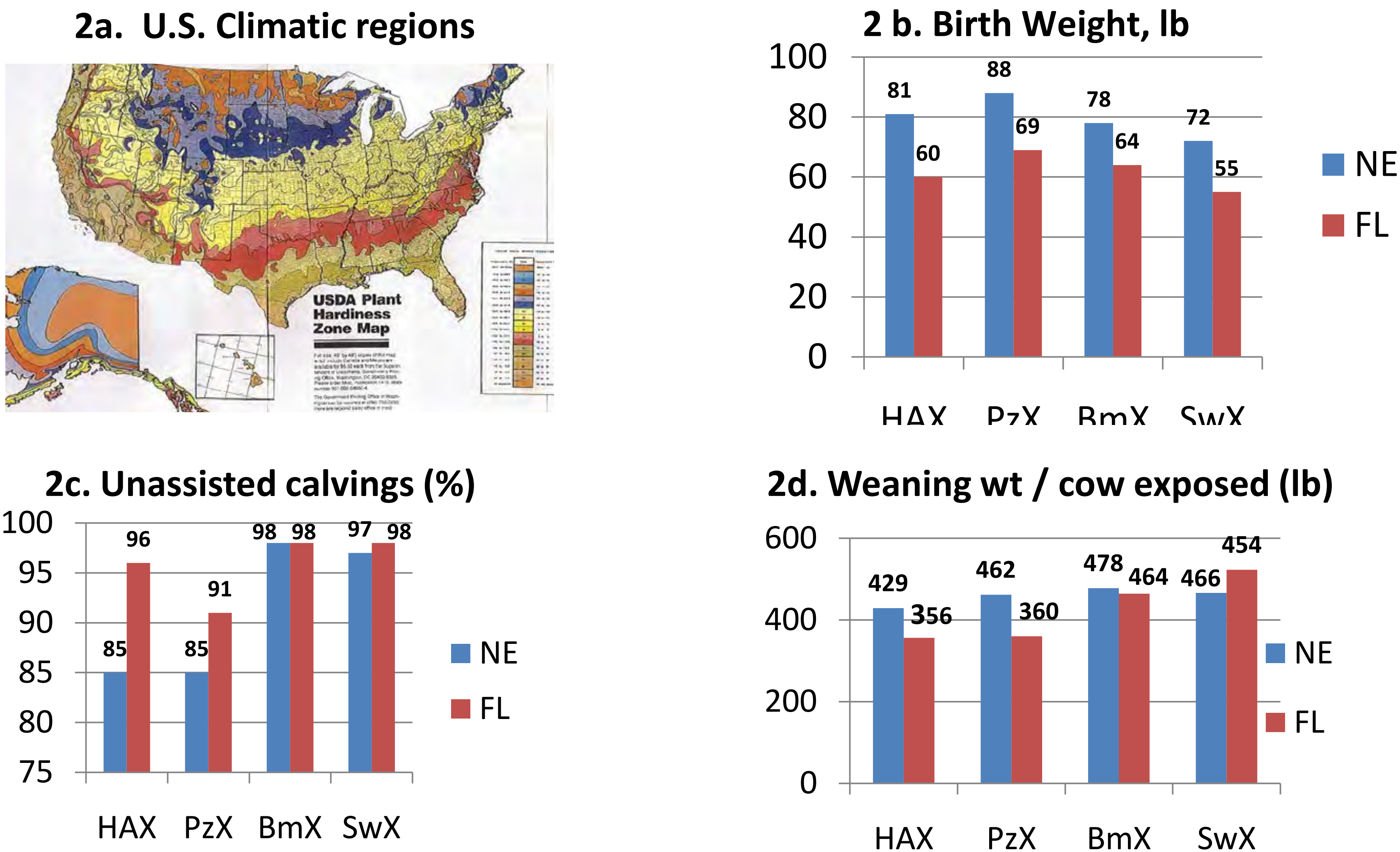

Figure 2. Matching Genetic Potential to the Climatic Environment (Olson et al., 1991) a. USDA Plant hardiness zone map , b. Birth weight (lb), c. Unassisted calvings (%), and d. Weaning Weight per cow exposed for Hereford-Angus reciprocal crosses (Hax), and Pinzgauer (PzX), Brahman (BmX) and Sahiwal (SwX) sired F_1 cross females calving at 2 through 6 years of age in Nebraska (NE) and Florida (FL).

TABLE 4. MORTALITY IN CALVES WITH DIFFERENT RATIOS OF *BOS INDICUS* TO *BOS TAURUS* INHERITANCE

Temp (F°)	*Bos indicus* to *Bos taurus* ratio [a]				
	0:100	25:75	50:50	75:25	Mean
>52	2	0	4	1	2
46 to < 52	2	5	0	4	2
41 to <46	5	0	4	36	11
36 to < 41	2	4	4	41	13
30 to < 36	1	2	22	37	16
< 30	3	8	12	9	8

[a] Backcross and F_2 matings among *Bos indicus* (Brahman and Sahiwal) and *Bos taurus* (Angus, Hereford, and Pinzgauer) breeds produced calves for this study (Josey et al., 1993)

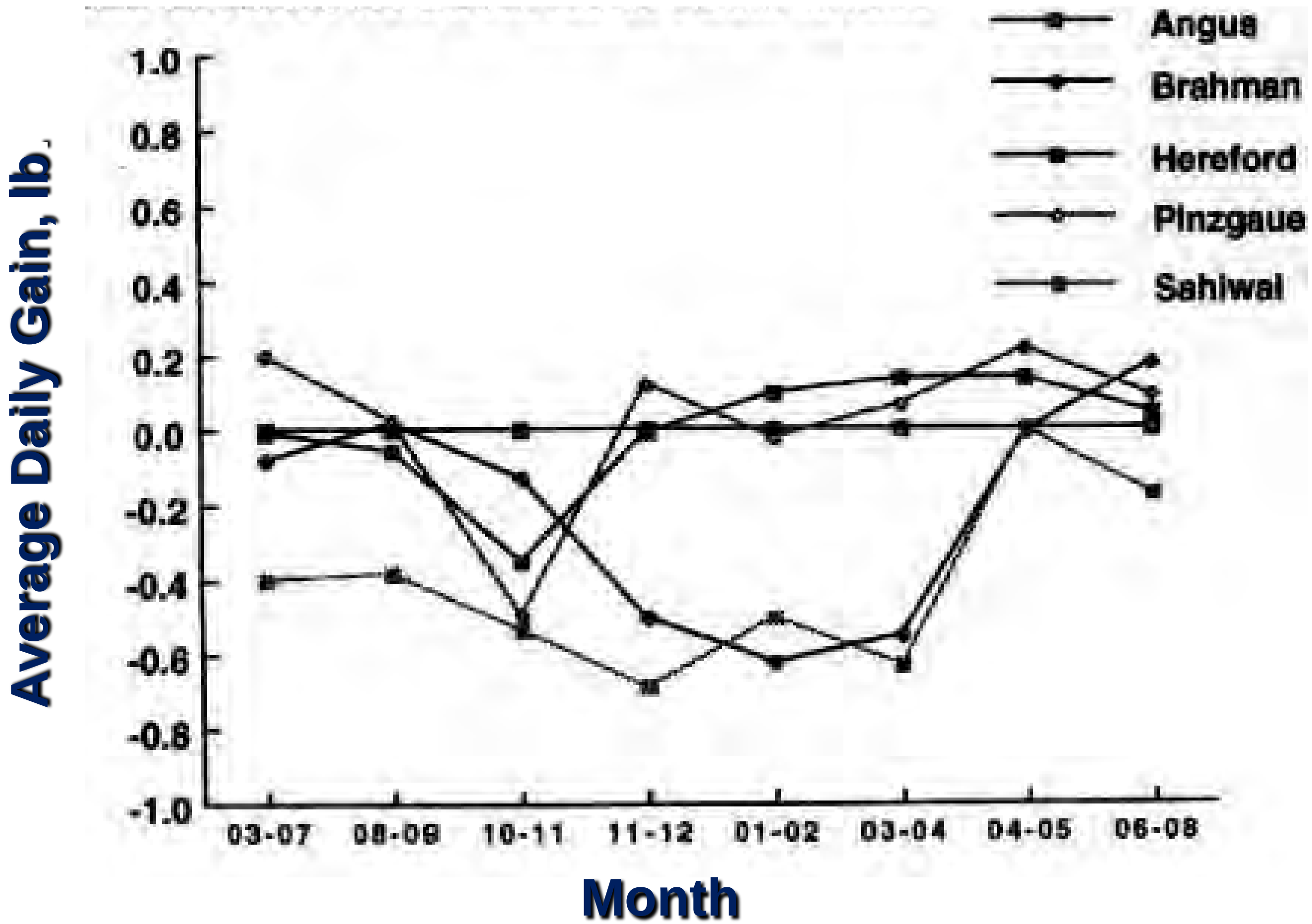

Figure 3. Breed Effects as Deviations from Angus for Average Daily in different seasonal periods (Souza et al., 1993)

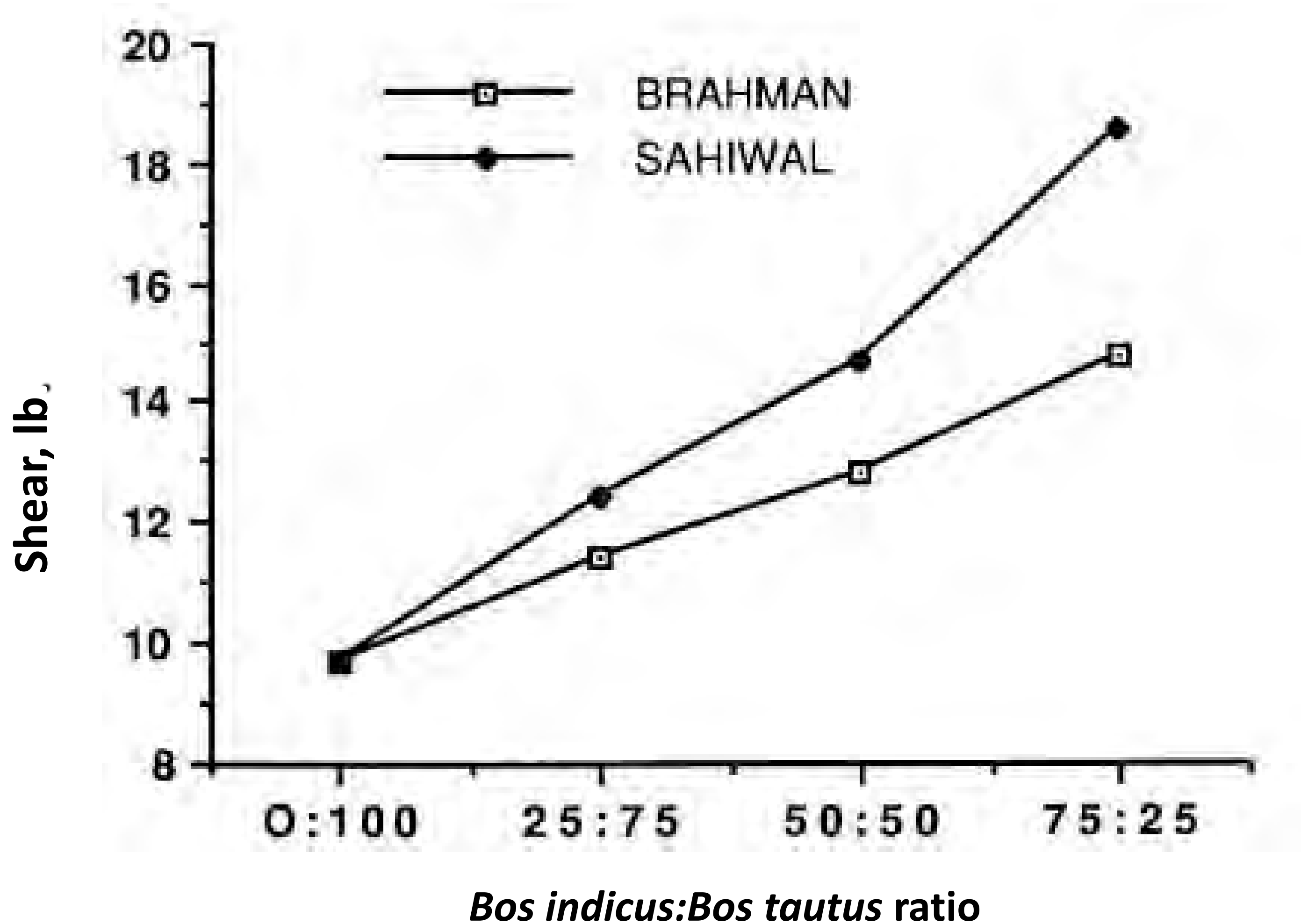

Figure 4. Shear values of cooked strip loin steaks from steers with different ratios *of Bos indicus:Bos taurus* inheritance (Crouse et al., 1989).

TABLE 5. OUTPUT/INPUT DIFFERENCES AMONG *BOS INDICUS* X *BOS TAURUS* AND *BOS TAURUS X BOS TAURUS* F_1 COWS

Item	Overall mean	Breed group [a] (ratio, %)			
		HAX	PzX	BmX	SwX
Progeny (126 days)					
Weight gain, lb	284.3	92	99	108	103
Energy consumed, Mcal ME	592.2	112	102	92	94
Dams (126 days)					
Milk production, lb/day	15.5	90	103	105	101
Cow weight, lb	1,236	98	100	105	97
Fat probe, in	.31	91	95	102	112
Energy consumed, Mcal ME	3,292	93	104	106	97
Efficiency (138.5 days)					
Progeny gain, lb/Mcal ME calf and dam	.073	95	95	105	106

[a] Hereford-Angus reciprocal crosses (Hax), and Pinzgauer (PzX), Brahman (BmX) and Sahiwal (SwX) sired F_1 cross females producing Charolais sired calves at 10 or 11 years of age (Green et al., 1991). Ratios are computed relative to the overall mean.

TABLE 6. SIRE BREED MEANS FOR WEIGHTS, FEED CONVERSION, AND CARCASS TRAITS (447d) OF F1 STEERS PRODUCED IN CYCYLE V OF THE GPE PROGRAM[a]

Sire breed	Birth wt lb	200 d wt lb	Final wt lb	Mcal per lb gain	Retail product %	Retail product lb	USDA Choice %	14-d Shear lb
Hereford	94.3	532	1270	----	61.9	449	70.3	10.6
Angus	90.3	528	1278	----	62.2	454	84.6	8.9
Average	92.3	530	1274	9.24	62.0	451	77.4	9.7
Brahman								
Early 70's sires	99.5	537	1174	----	64.1	434	29.4	13.4
Mid 80's sires	104.6	545	1199	----	63.8	449	30.4	12.9
Average	102.1	541	1186	10.30	63.9	444	29.9	13.2
Boran	95.6	508	1116	9.99	62.6	400	47.2	11.3
Tuli	85.8	496	1110	9.83	63.4	405	63.8	10.1
Nellore[b]	97.9	545	1224	10.41	65.0	465	51.4	----
LSD $\leq$ .05	3.4	15	48	.43	1.7	18	22.2	1.3

[a] Cycle V means from Cundiff et al. (2000).

[b] Nellore means estimated using deviations from Hereford-Angus crosses in Cycle IV of the GPE Program (Cundiff et al., 1993).

TABLE 7. SIRE BREED MEANS FOR REPRODUCTION AND MATERNAL TRAITS OF HEREFORD, ANGUS, AND TROPICALLY ADAPTED BREEDS EVALUATED IN CYCLES IV AND V OF THE GPE PROGRAM[a]

			2-years of age			3 to 7 years of age		
			Calf	200-day wt		Calf	200-day wt.	
Sire breed of female	No.	Age at puberty, Days	crop wnd. %	per calf lb	per cow exposed lb	crop wnd. %	per calf lb	per cow exposed lb
Hereford	152	355	74	419	300	89	474	422
Angus	130	351	74	437	313	86	493	426
Avg.	282	353	74	428	307	88	483	424
Brahman								
Early 70's	82	429	54	456	238	86	511	440
Mid 80's	208	423	70	476	319	83	521	430
Avg.	244	426	62	466	279	83	516	435
Boran	206	396	83	444	357	86	488	421
Tuli	244	371	75	413	296	84	471	397
Nellore[b]	82	406	75	463	324	92	514	461
LSD $\leq$ .05		13	14	18	62	7	14	36

[a] Cundiff et al. (2000)

[b] Nellore means estimated using deviations from Hereford-Angus crosses in Cycle IV of the GPE Program (Cundiff et al., 1993).

TABLE 8. SIRE BREED MEANS FOR PREWEANING TRAITS OF HEREFORD, ANGUS, BOS INIDUCUS AND BOS INIDICUS INFLUENCED SIRE BREEDS EVAPUATED IN CYCLE VIII OF THE GPE PROGRAM (WHEELER ET AL. 2006)

Sire breed of calf	No. calves born	Calvings unassisted %	Calving diff. score	Birth wt. lb.	200-d wn. wt., lb.
Hereford	212	94.4	1.33	91.1	534
Angus	208	97.2	1.19	87.1	541
Avg.	420	95.8	1.26	89.1	538
Brangus	214	96.9	1.19	90.5	549
Beefmaster	222	95.6	1.23	95.5	560
Bonsmara	207	97.7	1.10	90.4	533
Romosinuano	207	99.2	1.05	84.7	507
LSD $\leq$ .05		3.4	.20	3.0	11

TABLE 9. SIRE BREED MEANS FOR FINAL WEIGHT, FEED CONVERSION AND CARCASS TRAITS OF F_1 STEERS PRODUCED IN CYCLE VIII OF THE GPE PROGRAM (426 DAYS) (Wheeler et al., 2006)

Sire Breed	N	Final wt lb	Mcal per lb gain	Retail product %	Retail product lb	Marb. score	USDA Choice %	W-B shear lb
Hereford	102	565	7.65	61.8	465	515	52	8.1
Angus	103	582	7.61	60.0	469	548	71	7.6
Avg.	205	571	7.63	60.9	467	532	62	7.8
Brangus	107	570	7.82	62.1	480	497	42	8.6
Beefmaster	103	588	7.81	61.2	482	483	35	9.0
Bonsmara	104	538	8.17	63.4	464	487	37	8.1
Romosinuano	102	522	7.86	64.4	452	488	37	8.3
LSD < .05		14	.34	1.1	13	24	13	0.5

TABLE 10. SIRE BREED MEANS FOR REPRODUCTION AND MATERNAL TRAITS OF F1 FEMALES CALVING AT 2 YEARS OF AGE IN NEBRASKA AND LOUISIANA (Cundiff and Franke, 2006; Franke and Cundiff, 2006)

Sire breed of female	Louisiana				Nebraska			
	Age at puberty days	Calf crop weaned %	205-day wt per calf lb	205-day wt per cow exposed lb	Age at puberty days	Calf crop weaned %	205-day wt. per calf lb	205-day wt. per cow exposed lb
Hereford	- - -	- - -	- - -	- - -	327	77	461	354
Angus	- - -	- - -	- - -	- - -	309	68	481	325
Brangus	332	73	398	288	340	83	488	403
Beefmaster	342	69	417	289	344	85	496	421
Bonsmara	336	70	409	288	352	72	461	333
Romosinuano	330	68	377	256	359	79	420	334
LSD < .05	22	17	26	48	22	17	26	48

TABLE 11. SIRE BREED MEANS FOR REPRODUCTION AND MATERNAL TRAITS OF F_1 FEMALES CALVING AT 3 – 7 YEARS OF AGE IN NEBRASKA AND LOUISIANA (Preliminary Analyses, Cundiff and Franke)

	Louisiana				Nebraska			
			205-day wt				205-day wt.	
Sire breed of female	Number exposed	Calf crop weaned %	per calf lb	per cow exposed lb	Number exposed	Calf crop weaned %	per calf lb	per cow exposed lb
Hereford	- - -	- - -	- - -	- - -	347	84.7	567	479
Angus	- - -	- - -	- - -	- - -	360	87.1	588	511
Brangus	210	84.3	486	412	184	87.5	583	508
Beefmaster	238	86.0	505	434	193	87.3	592	516
Bonsmara	195	85.3	500	426	175	88.7	565	502
Romosinuano	203	88.5	488	433	196	90.4	522	472
LSD < .05		7.4	21	48		7.4	21	48

TABLE 12. BREEDS GROUPED INTO BIOLOGICAL TYPES FOR SEVEN CRITERIA[a]

Breed	Growth rate and Mature size	Lean to fat ratio	Marbling	Tender-ness	Age at puberty	Milk pro-duction	Tropical Adaptation
Jersey	X	X	XXXX	XXX	X	XXXXX	XX
Longhorn	X	XXX	XX	XX	XXX	XX	XX
Wagyu	X	XXX	XXXX	XXX	XX	XX	XX
Angus	XXXXX	XX	XXXXX	XXX	XX	XXXx	X
Red Angus	XXXX	XX	XXXX	XXX	XX	XXX	X
Hereford	XXXX	XX	XXX	XXX	XXX	XX	X
Red Poll	XX	XX	XXX	XXX	XX	XXXX	X
Devon	XX	XX	XXX	XXX	XXX	XX	X
Shorthorn	XXXX	XX	XXXX	XXX	XX	XXXx	X
Galloway	XX	XXX	XXX	XXX	XXX	XX	X
Braunvieh	XXX	XXXX	XX	XX	XXXX	XX	XX
Gelbvieh	XXXX	XXXXX	X	XX	XX	XXXX	X
Holstein	XXXXX	XXXX	XXX	XX	XX	XXXXXX	X
Maine Anjou	XXXX	XXXX	XX	XX	XXX	XXX	X
Salers	XXXX	XXXX	XXXX	XX	XXX	XXXx	X
Norwegian Red	XXXX	XXXX	XXX	XX	XX	XXXX	X
Swedish Red & White	XXXX	XXXX	XXX	XX	XX	XXXX	X
Friesian	XXXX	XXXX	XXX	XX	XX	XXXX	X
Simmental	XXXXX	XXXX	XX	XX	XXX	XXXx	X
Limousin	XXXX	XXXXX	X	XX	XXXX	X	X
Charolais	XXXXX	XXXXX	XX	XX	XXXX	XX	X
Piedmontese	XX	XXXXXX	X	XXX	XX	XX	XX
Belgian Blue	XXX	XXXXXX	X	XXX	XX	XX	X
Romosinuano	X	XXX	XX	XX	XXX	XXX	XXX
Tuli	XX	XXX	XXX	XX	XXX	XXX	XXX
Brangus	XXXX	XXX	XXX	XX	XXX	XXX	XXX
Beefmaster	XXXX	XXX	XX	XX	XXX	XXX	XXX
Santa Gertrudis	XXXX	XXX	XX	XXX	XXX	XXX	XXX
Bonsmara	XXX	XXX	XX	XX	XXX	XXX	XXX
Brahman	XXXX	XXXX	XX	X	XXXXX	XXXX	XXXX
Nellore	XXXX	XXXX	XX	X	XXXXX	XXX	XXXX
Boran	XXX	XXX	XX	X	XXX	XXX	XXXX
Sahiwal	XX	XXXX	XX	X	XXXX	XXXX	XXXX

[a] Increasing numbers of X's indicate higher values with lower case x's indicating intermediate values.

TABLE 13. BEEF BREED REGISTRATIONS
(National Pedigreed Livestock Council Bi-Annual Reports)

Year	British					Continental					American					Total 1000s
	A	H	Sh	RA	Total %	C	S	L	G	Total %	Bm	SG	Brg	Bfm	Total %	
1965	34.6	56.0	3.4	0.2	94.3	2.8				2.8	1.4	1.1	0.4		2.9	1,113
1970	40.0	45.0	4.0	0.6	89.9	5.1				5.1	2.1	2.2	0.7		5.0	882
1975	29.2	39.9	2.8	0.8	73.1	7.4	8.0		0.9	19.7	2.6	2.1	1.3	1.2	7.3	1,049
1980	28.1	38.5	2.1	1.1	70.2	2.9	7.4	4.3	0.5	17.1	4.0	2.8	2.7	3.3	12.7	917
1985	22.3	26.1	2.4	1.8	52.9	3.9	12.2	6.0	2.3	29.9	4.3	3.8	4.4	4.7	17.1	700
1990	21.5	23.1	2.4	2.1	49.4	6.3	10.6	9.8	3.1	36.2	1.8	2.0	4.3	6.3	14.4	738
1995	28.7	14.8	2.0	3.8	49.7	7.1	9.1	10.1	4.3	37.6	1.9	1.5	3.6	5.6	12.7	784
2000	37.5	12.2	2.7	5.7	58.0	6.1	6.2	7.0	3.8	29.3	2.6	1.5	3.9	4.6	12.7	696
2005	41.7	9.6	2.5	6.0	59.8	10.3	6.1	5.5	3.8	31.9	1.1	1.0	3.2	2.7	8.0	777
2007	44.1	8.8	2.5	6.0	61.3	9.5	6.6	4.8	4.6	30.8	1.1	1.0	3.2	2.3	7.5	789
2009	44.8	8.6	2.1	6.4	61.9	8.8	6.1	3.9	4.7	28.6	1.1	1.0	4.0	2.0	8.1	745