Implications of Breed Type Evaluations

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Introduction

Quality, quantity, and cost of feed resources available for beef production vary from one region of the country to another and within regions, depending upon climatic factors and natural resources available in specific production situations. Diversity among breeds can be exploited by crossbreeding to optimize performance levels and to match genetic resources with the climatic environment, feed resources, and consumer preferences for lean and tender beef products. Crossbreeding also provides for significant benefits of heterosis on components of production efficiency. In this presentation, research results will be reviewed focusing on effects and utilization of heterosis and breed differences, and on the importance of matching genetic potential with consumer preferences and the climatic environment.

Heterosis

A crossbreeding experiment involving Herefords, Angus, and Shorthorns demonstrated that weaning weight per cow was increased by about 23% (Cundiff et al., 1974) due to beneficial effects of heterosis on survival and growth of crossbred calves and on reproduction rate and weaning weight of calves from crossbred dams (Figure 1). More than half of this advantage was due to use of crossbred cows. Effects of heterosis are greatest for longevity (Nunez et al., 1991) and lifetime production (Cundiff et al., 1992) of cows (Table 1). For comprehensive traits such as lifetime production, cumulative effects of heterosis are rather large and the performance of each specific cross usually exceeds that of either parent breed. For example, longevity and lifetime production of Hereford X Angus and Angus X Hereford cows was significantly greater than that of either straightbred Angus or Herefords (Nunez et al., 1991; Cundiff et al., 1992). Crossing of *Bos indicus* and *Bos taurus* breeds yields even higher levels of heterosis, averaging about twice as large as estimates reported for corresponding traits in crosses among *Bos taurus* breeds (Cartwright et al., 1964; Turner et al., 1968; Koger et al., 1975).

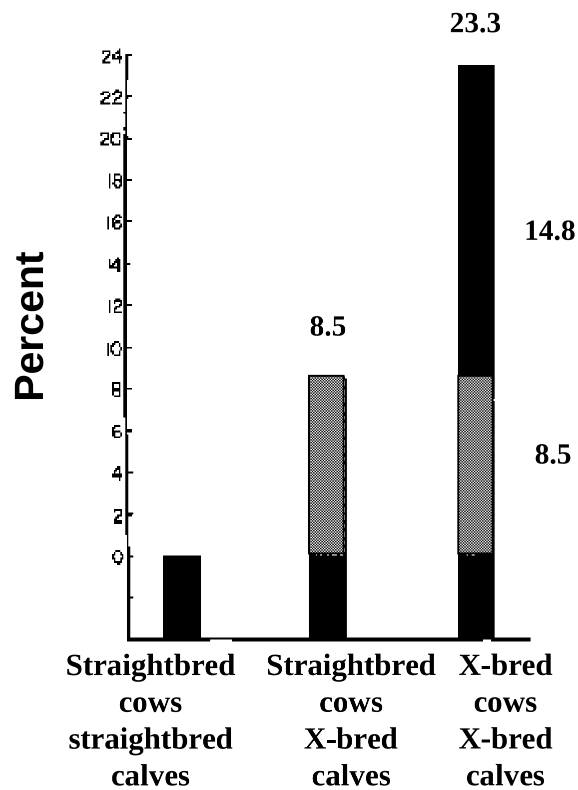


Figure 1. Cumulative effects of heterosis for weight of calf weaned per cow exposed to breeding in crosses of Hereford, Angus, and Shorthorns (Cundiff et al., 1974).

Rotational Crossbreeding

In the experiment involving Herefords, Angus, and Shorthorns conducted at the U.S. Meat Animal Research Center (MARC), it was demonstrated that

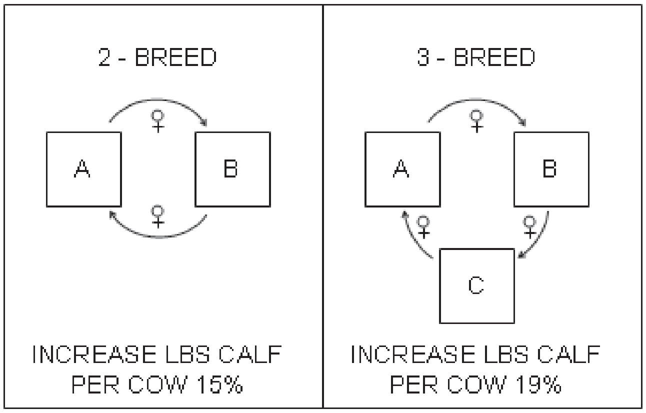


Figure 2. Rotational crossbreeding systems.

significant levels of heterosis were maintained from generation to generation by rotational crossbreeding of Herefords, Angus, and Shorthorns (Figure 2). The level of heterosis retained was proportional to expected heterozygosity (Gregory and Cundiff, 1980). It is important to use breeds that are reasonably comparable in rotational crossbreeding systems to provide for uniformity in traits such as birth weight to minimize calving difficulty, size, and milk production to stabilize feed requirements in cow herds, and carcass and meat characteristics. Breed composition fluctuates widely from one generation to the next with rotational crossbreeding. For example in two-breed rotation after the sixth generation and on the average over all generations, 67% of the genes of the cows are of the breed of their sire and 33% are of the breed of their grandsire, the latter being the same as the breed to which they are to be mated.

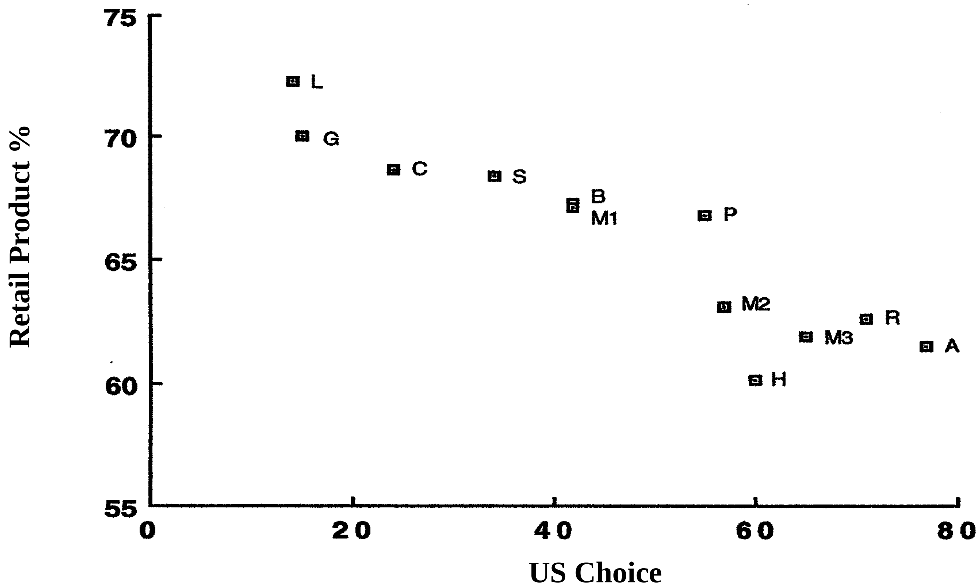
Composite Populations

Composite populations, developed by *inter se* mating of animals resulting from crossing of two or more breeds, have management requirements that are comparable to straight-breeding. Results of a comprehensive experiment involving four generations of *inter se* mating in three composite populations demonstrated that significant levels of heterosis are retained in composite populations (Gregory et al., 1999). In this experiment performance of each composite population (Composite MARC I was $^{1}/_{4}$ Charolais, $^{1}/_{4}$ Braunvieh, $^{1}/_{4}$ Limousin, $^{1}/_{8}$ Hereford, and $^{1}/_{8}$ Angus; Composite MARC II was $^{1}/_{4}$ each Simmental, Gelbvieh, Angus, and Hereford; and Composite MARC III was $^{1}/_{4}$ each Pinzgauer, Angus, Hereford, and Red Poll) was compared to performance of the purebreds that contributed to the foundation of each composite population. Effects of heterosis (F_1 minus Purebreds) and retained heterosis in advanced generations ($F_2 = F_1$ X F_1 matings, $F_3 = F_2$ X F_2 matings, and $F_4 = F_3$ X F_3 matings) are summarized in Table 2. Heterosis was maintained proportional to heterozygosity in composite populations. Since heterosis is retained proportional to heterozygosity, significant levels of heterosis can be maintained by rotational crossing of F_1 seedstock (e.g., F_1 cross Gelbvieh X Angus, or Simmental X Hereford) or by rotational crossing of composite populations (e.g., Brangus, Beefmaster) as well.

Uniformity of cattle and greater consistency of end product can be provided for with greater precision by use of F_1 seedstock or composite populations than by use of rotational crossing of purebreds. For example, with current pricing systems, cattle with 50:50 ratios of Continental to British breed inheritance have more optimal carcass characteristics, and experienced fewer discounts for excessive fatness (yield grade 4 or more) or for low levels of marbling (USDA Standard quality grades or less) than cattle with lower or higher ratios of Continental to British inheritance. This is caused by a strong genetic antagonism between USDA quality grade and percentage retail product (Figure 3). Retail product is closely trimmed (0.0 inches) boneless steaks, roasts, and lean trim (ground beef containing 20% fat). In the Germplasm Utilization Program at MARC, steers representing Continental European breeds (Charolais, Simmental, Braunvieh, Gelbvieh, Pinzgauer) excelled in retail product percentage but had difficulty grading USDA Choice because of lower levels of marbling. British breeds (e.g., Angus, Hereford, Red Poll) excelled in USDA quality grade because of higher levels of marbling but had reduced retail product yield due to excessive fat thickness and fat trim.

Breed Differences

Table 3 shows the mating plan for the first



Limousin (L), Gelbvieh (G), Charolais (C), Simmental (S), Braunvieh (B), Pinzgauer (P), Hereford (H), Red Poll (R), Angus (A), and composites MARC I (M1, ¼ Charolais, ¼ Braunvieh, ¼ Limousin, 1/8 Angus, 1/8 Hereford), MARC II (M2, ¼ Angus, ¼ Hereford, ¼ Simmental, and ¼ Gelbvieh), and MARC III (M3 = ¼ Angus, ¼ Hereford, ¼ Red Poll, and ¼ Pinzgauer).

Figure 3. Retail product versus percent USDA Choice in purebreds and composite populations (Gregory et al., 1999).

eight cycles of the Germplasm Evaluation (GPE) Program at MARC. Each Cycle is an experiment conducted over a time span of about 10 years. Topcross performance of 34 sire breeds has been evaluated in F_1 calves out of Hereford, Angus, or Composite MARC III (starting with Cycle V) dams. Hereford and Angus sires have been used in each Cycle of the program to provide ties for analysis of data pooled over cycles. Some of the Hereford and Angus sires used in Cycle I were repeated in Cycles II, III, and IV (60 to 70s sires). Later, many of the Hereford and Angus sires used for the first time in Cycle IV were repeated in Cycle V (80s sires). Similarly, many of the Brahman sires used in Cycle III (70s sires) were repeated in Cycle V and compared to a new sample of Brahman sires born in the 1980s (80s sires). As a general rule in each cycle, about 200 progeny per sire breed were produced from artificial insemination (AI) to 20 to 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.

Calves were born in the spring and weaned in the fall at about 7 months of age. Male calves were castrated within 24 hours of birth. Following weaning, steers were fed a diet containing about 2.8 Mcal metabolizable energy per kg dry matter. Data will be presented for steers that were slaughtered in three to four slaughter groups spaced 21 to 28 days apart. All F_1 females were retained to evaluate growth, age at puberty, reproduction, and maternal performance in three-way cross progeny produced at 2 through 7 or 8 years of age.

Prominent *Bos taurus* breeds. In Cycle VII of the GPE Program (Cundiff et al., 2004), the seven most prominent beef breeds in the U.S., according to registrations in breed associations (National Pedigreed Livestock Council, 2002), were evaluated (Table 4). Angus, Hereford, Limousin, Simmental, Charolais, and Gelbvieh had been characterized in Cycle I or Cycle II of the GPE

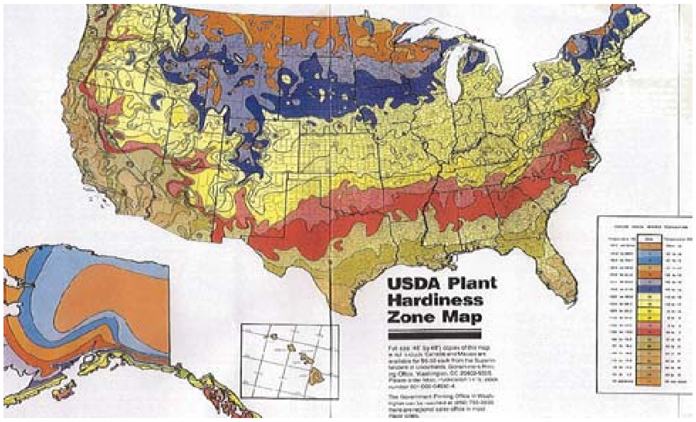
Program (Table 3). Red Angus cattle were evaluated for the first time in Cycle VII.

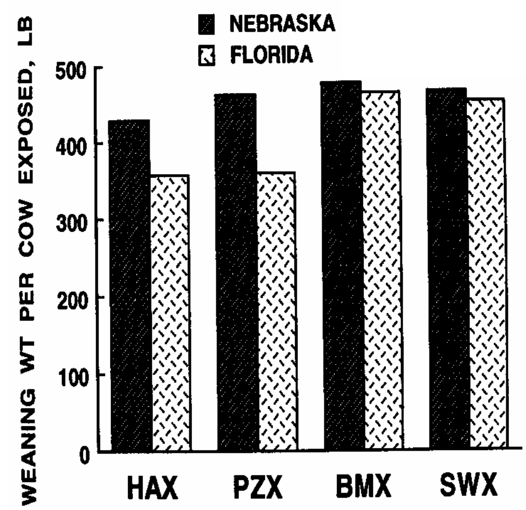
Sire breed means for final slaughter weight (445 days) and certain carcass and meat traits are shown in Table 5. The differences for slaughter weight (445 days) between progeny of Continental sire breeds compared to British sire breeds were considerably less than when they were evaluated 25 to 30 years earlier. However, differences between Continental and British breeds in retail product percentage, marbling score, and percentage grading USDA Choice were about the same as they were in Cycle I and Cycle II of the program. Carcasses from progeny of Limousin, Gelbvieh, Charolais, and Simmental sires had significantly higher retail product percentages and yield grades than carcasses from progeny of Hereford, Angus, and Red Angus sires. However, marbling was significantly greater in progeny of Red Angus and Angus sires than in progeny of Charolais, Hereford, Gelbvieh, and Limousin sires. Rib steaks from Angus sired progeny were significantly more tender than those from Gelbvieh sired progeny according to shear force evaluations. British breed crosses (Table 6) had a higher percentage of yield grade 4 carcasses than Continental European breed crosses (Table 7). Results in Cycle VII are consistent with earlier results indicating that cattle with 50:50 contributions of Continental to British inheritance are more optimal for current market grids than cattle with lower or higher ratios of Continental to British inheritance.

Post-weaning growth and puberty traits are shown in Table 8. Sire breed differences between British and Continental sire breeds for body weights at 400 days or 18 months of age in progeny of sires born in Cycle VII (born in 1999-2000) were not as great as they were in Cycle I and II (1970-1974) of the GPE Program and reflected considerable re-ranking among breeds. These results are consistent with estimates of expected progeny differences published by breed associations which also indicate that genetic trends have been greater for yearling weights in British breeds than in Continental European breeds. However, hip heights and frame scores were significantly greater for heifers with Simmental, Charolais, and Limousin sires than for those with Angus and Red Angus sires. Age at puberty was greater in Limousin sired heifers than all other sire breeds and younger in Gelbvieh sired heifers than in Hereford, Angus, and Red Angus sired heifers. Breeds that have had a history of selection for milk production (e.g., Simmental and Gelbvieh) reached puberty earlier than breeds that have not been selected for milk production (all other breeds).

Data reported for reproduction and maternal performance are especially preliminary, representing only the first of seven calf crops to be produced by the F_1 females (Table 9) exposed to MARC III bulls and calving at 2 years of age. Breed of sire of the F_1 dams calving at 2 years of age was not a significant source of variation for any of the traits summarized, except 200-day weaning weight per calf weaned. Weaning weights of progeny raised by F_1 females with Gelbvieh and Simmental sires were significantly heavier than those with Charolais, Limousin, and Angus sires. Weaning weights of progeny raised by F_1 females with Hereford sires were significantly lighter that those by any other sire breed, except Red Angus. Contrasts between British and Continental European breeds are less than half as great for direct and maternal weaning weight today as they were 25 to 30 years ago.

Tropically adapted breeds. Use of *Bos indicus X Bos taurus* crosses (e.g., Brahman X Hereford) is greatly favored in the subtropical regions of the U.S. In a cooperative effort between the Subtropical Agricultural Research Station (STARS), Brooksville, Florida, ARS, USDA, the University of Florida, and MARC, weaning weight per cow exposed was significantly greater for the *Bos indicus* X *Bos taurus* F_1 crosses (Brahman X Hereford, Brahman X Angus, Sahiwal X Hereford, Sahiwal X Angus) than for the *Bos taurus* X *Bos taurus* F_1 crosses (Hereford X Angus, Angus X Hereford, Pinzgauer X Hereford, Pinzgauer X Angus) at both locations, but the advantage was especially large in Florida (Figure 4) (Olson et al., 1991). Results at MARC also indicated that cow efficiency (pounds of calf gain per unit of feed





HAX = Hereford X Angus, PZX = Pinzgauer, BMX = Brahman, and SWX = Sahiwal crosses

Figure 4. Matching genetic potential to the climatic environment (Olson et al., 1991).

consumed by the cow and calf), estimated during lactation in summer months, was exceptional for *Bos indicus* X *Bos taurus* relative to Hereford-Angus crosses (Table10) (Green et al., 1991), which were in turn relatively efficient compared to other *Bos taurus* X *Bos taurus* crosses (Table 11) (Jenkins et al, 1991). Reproduction rate, weaning weight per cow exposed, and cow efficiency is outstanding in *Bos indicus* X *Bos taurus* F_1 crosses, especially in subtropical climatic environments, but their advantages are tempered by older age at puberty and reduced meat tenderness as the proportion of *Bos indicus* increases (Crouse et al., 1989). Concerns about meat quality and reproduction rate at young ages have prompted introduction and evaluation of other tropically adapted germplasm in cooperative research efforts involving MARC and research stations in subtropical regions of the U.S. (i.e., Texas, Oklahoma, Florida, Georgia, and Louisiana) with contributing projects to Regional Project S-277.

In Cycle V of the Germplasm Evaluation Program at MARC (Table 12), 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 (nonhumped), originates from Africa. Semen from nine Tuli bulls was imported from Australia for use in the experiment. 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) by embryo transfer at the same time as the Tuli. Semen from eight Boran bulls was imported from Australia for use in the experiment.

Performance of Nellore crosses, also shown in Table 12, 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 between

Nellore crosses and other breeds can be approximated by multiplying 1.5 times the least significant difference shown in Tables 12 and 13 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 12). 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 larger percentages of calf crop weaned as 2-year-olds than Brahman crosses (Table 13). 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. Tuli germplasm may be useful to replace a portion of *Bos indicus* breeding and maintain tropical adaptation without detrimental effects on meat tenderness, provided they are crossed with other breeds that optimize size and growth rate. Cooperative research efforts have been completed recently to evaluate reproduction and maternal performance of F_1 cows by Tuli, Boran, and Brahman sires at research stations located in subtropical regions of the U.S. (i.e., Florida, Georgia, Texas, Louisiana, and Oklahoma). However, data have not yet been pooled and analyzed over all locations to assess the importance of genotype-environment interactions for these traits.

In Cycle VIII of the GPE Program Brangus, Beefmaster, Bonsmara, and Romosinuano are being evaluated relative to Hereford and Angus crosses. Beefmaster and Brangus were included in Cycle VIII because they are prominent breeds used extensively in subtropical regions of the U.S. ranking 8^{th} and 9^{th} in registrations among U.S. beef breeds (Table 4). Bonsmara are a composite breed that was developed in South Africa from approximately 50% Africaner (an African Sanga breed), 25% Hereford, and 25% Shorthorn foundation matings. Semen was used from 19 Bonsmara bulls purchased from Mr. George Chapman, Amarillo, TX who imported the breed into the United States. Semen from 20 Romosinuano bulls was used. The Romosinuano breed was developed primarily in Colombia and introduced into the U.S. from Venezuela at the STARS, ARS, USDA and the University of Florida. 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.

Estimates of sire breed means averaged over Angus and MARC III dams are shown in Table 14 for preweaning traits. Breed of sire effects were significant ($P < 0.01$) for birth weight, and 205-day weaning weight, but not for percentage unassisted births or calving difficulty score. Birth weights of Romosinuano sired progeny were significantly lighter than those of any other breed except Angus. Angus sired progeny were lighter at birth than those with Bonsmara, Brangus, or Hereford sires. Birth weight did not differ significantly among progeny of Bonsmara, Brangus, and Hereford sires. Progeny of Beefmaster sires were significantly heavier at birth than those of any other sire breed. Weaning weight at 205 days was significantly heavier for progeny of Beefmaster sires than for any other sire breed, followed by Brangus and Angus, which did not differ significantly. Brangus sired progeny were significantly heavier at weaning than Hereford sired progeny. Angus, Hereford, and Bonsmara sire breeds did not differ significantly in weaning weight. Romosinuano sired progeny were significantly lighter at weaning than those of any other sire breed.

Breed of sire means for postweaning growth rate and final weight of steers and carcass traits adjusted to 426 days of age are provided in Table 15. Breed of sire means differed significantly ($P < 0.01$) for postweaning average daily gain, final weight, percentage, and weight of retail product, marbling score, and percentage grading USDA Choice or higher. Postweaning average daily gains were significantly greater for Angus than all other breeds except Beefmaster. Beefmaster, Hereford, and Brangus sired steers had significantly greater postweaning average daily gains than Bonsmara and Romosinuano sired steers. Beefmaster sired steers had significantly heavier final weights than all other breeds except Angus. Angus, Brangus, and Hereford sired steers were 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. Angus sired steer carcasses had significantly lower percentages of retail product than those by any other sire breed. 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 the other four sire breeds - Angus, Hereford, Bonsmara, and Romosinuano. Hereford, Angus, and Bonsmara did not differ significantly for weight of retail product. Steer progeny of Romosinuano sires had significantly lower weights of retail product than those of all other sire breeds except Bonsmara. Marbling score and percentage grading USDA Choice or higher were significantly greater for Angus than for any other sire breed. Carcasses from 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 Beefmasters.

Half of the Brangus, Beefmaster, Bonsmara, and Romsinuano females being produced at MARC were transferred at about 8 months of age from MARC to Louisiana State University to evaluate genotype-environment interactions. Data summarizing growth and puberty characteristics of females in Tables 16 and 17, are for only the heifers produced which remained at MARC. The Brangus, Beefmaster, Brangus, and Romosinuano sired progeny represent only about 50% of the females being evaluated in the cooperative experiment. Results for growth of heifers are generally consistent with that of steers indicating that Beefmaster and Angus sired females had the greater growth rates to 400 days than all other sire breeds except Brangus. By 400 days, Brangus and Herefords did not differ significantly in body weight, but both were heavier than Bonsmara or Romosinuano sired females. By 18 months of age, after the summer gazing season, Beefmaster were significantly heavier than all other breeds except Brangus. Brangus sired heifers were significantly heavier at 18 months of age than Romosinuano sired females, but did not differ significantly from Hereford, Bonsmara, or Angus sired females, which had similar 18 month weights. Brangus and Beefmaster sired heifers had significantly greater hip heights and frame scores at 18 months of age than Hereford, Bonsmara, Angus, or Romosinuano sired heifers. Hereford sired heifers ranked third in hip height and frame score and were significantly taller than Romsinuano sired heifers. Bonsmara, Angus, and Romosinuano sired heifers did not differ in hip height or frame score at 18 months of age. Analysis of variance indicated that effects of sire breed were significant for age at puberty ($P < 0.05$) but not for pregnancy rate (Table 17). Females by Angus sires reached puberty at a significantly younger age than those by any other sire breed. Hereford sired females ranked second and were significantly younger at puberty than Brangus, Beefmaster, and Bonsmara sired females which did not differ significantly. Females by Romosinuano sires reached puberty at significantly older ages than females by any other sire breed except Bonsmara.

Implications

The beef industry is challenged to 1) reduce costs of production to remain competitive in global markets, 2) match genetic potential with the climate and feed resources available in diverse environments, 3) reduce fat and increase leanness of products to gain greater acceptance of consumers, and 4) improve palatability, tenderness, and consistency of beef products. Use of heterosis and breed differences through use of crossbreeding or composite populations, and selection of breeding stock to exploit genetic variation within breeds can all be used to help meet these challenges.

Effects of heterosis increase production per cow about 20% to 25% in *Bos taurus* crosses (e.g., Angus X Hereford) and at least 50% in *Bos indicus* X *Bos taurus* breed crosses (e.g., Brahman X Shorthorn). Significant levels of heterosis are maintained by rotational systems of crossbreeding and in composite populations. Rotational systems of crossbreeding provide for more effective use of heterosis than composite populations for any specific number of breeds. However, uniformity of cattle and greater consistency of end product can be provided for with greater precision by use of F_1 seedstock or composite populations than by use of rotational crossing of pure breeds.

No one breed excels in all traits of importance to beef production. Thus, crossing of two or more breeds can be used to optimize performance levels. In temperate environments, 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 to British inheritance.

A strong influence of tropically adapted germplasm is needed in subtropical regions of the U.S. to limit costs and improve efficiency of production. In the hotter and more humid climates of the Gulf Coast, about 50:50 ratios of *Bos indicus* to *Bos taurus* inheritance may be optimal. A little further north (e.g., southeastern Oklahoma, central Arkansas, Tennessee, and parts of North Carolina), 25:75 ratios of *Bos indicus*: *Bos taurus* inheritance may be optimal in cowherds. In temperate climates (e.g., Nebraska), crosses with 50% or more *Bos indicus* inheritance suffer increased mortality when calves are born in colder seasons and reduced average daily gains in feedlots during winter months. Use of F_1 Brahman cross cows, Nellore, or Boran F_1 cross cows or rotational crossing of composite breeds such as Beefmaster, Brangus, Bonsmara, or Santa Gertrudis are especially appropriate in subtropical environments. 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.

In developing composite populations with an overall level of 50% tropical adaptation, it may be appropriate to substitute a portion (e.g., 25%) of non *Bos indicus* germplasm for *Bos indicus* germplasm from such breeds as the Tuli, Romosinuano, or Senepole to maintain tropical adaptation and improve meat tenderness, provided they are crossed with other breeds that optimize size and growth rate. However, additional research is needed to determine optimum contributions of *Bos indicus*, British *Bos taurus*, Continental *Bos taurus*, tropically adapted Sanga breeds, and tropically adapted Criollo breeds from Central and South America in beef production in subtropical environments of the U.S.

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Table 1. Longevity and lifetime production of straightbred Hereford (H), Angus (A), Hereford X Angus (HA), and Angus X Hereford (AH) cows.

	Breed group				
Trait	H	A	HA	AH	Heterosis
Longevity, yrs	8.4	9.4	11.0	10.6	1.9*
Lifetime production					
No. calves	5.9	6.6	7.6	7.6	1.3*
Wt of calves weaned, lb	2,045	2,837	3,518	3,514	766*

*P < .05

Table 2. Heterosis effects and retained heterosis in composite populations versus contributing purebreds (Gregory et al., 1999).

	Composites minus purebreds		
Trait	F_1	F_2	$F_{3\&4}$
Birth wt, lb	3.6	5.0	5.1
200 d wn wt, lb	42.4	33.4	33.7
365 d wt, females, lb	57.3	51.4	52.0
365 d wt, males, lb	63.5	58.6	59.8
Age at puberty, females, d	-21	-18	-17
Scrotal circumference, in	0.51	0.35	0.43
200 d weaning wt (mat), lb	33	36	
Calf crop born (mat), %	5.4	1.7	
Calf crop wnd (mat), %	6.3	2.1	
200 d wn wt/cow exp (mat), lb	55	37	

Table 3. Sire breeds used to produce F_1 crosses with Angus and Hereford dams in the germplasm evaluation program at MARC.[a]

Cycle I 70-72	Cycle II 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 (¼ Angus, Hereford, Red Poll, and Pinzgauer) females were also included in Cycles V, VI, and VII. In cycle VIII, sire breeds were mated to Angus and MARC III females.

Table 4. Beef breed registrations (National Pedigreed Livestock Council, 2002).

Breed	Registrations	%	Breed	Registrations	%
Angus	271,222	37.9	Maine Anjou	12,267	1.7
Hereford	80,976	11.3	Santa Gertrudis	11,500	1.6
Limousin	49,036	6.9	Salers	10,286	1.4
Simmental	44,159	6.2	Longhorn	6,200	0.9
Charolais	45,354	6.3	Chianina	6,679	0.9
Red Angus	41,900	5.9	Braunvieh	6,235	0.9
Gelbvieh	32,323	4.5	Tarentaise	1,900	0.3
Beefmaster	30,416	4.3	Highland	1,500	0.2
Brangus	25,500	3.6	Pinzgauer	664	0.1
Shorthorn	21,608	3.0	Bl d'Aquitaine	625	0.1
Brahman	15,000	2.1	Total	715,350	100

Table 5. Sire breed means for final weight and carcass traits of F_1 steers (445 days).

			Retail product			
Sire breed	N	Final wt, lb	%	lb	USDA Choice, %	WB shear, lb
Hereford	97	1,322	60.7	480	70	9.1
Angus	98	1,365	59.2	488	95	8.9
Red Angus	93	1,333	59.1	474	93	9.2
Simmental	92	1,363	63.0	522	61	9.5
Gelbvieh	90	1,312	63.8	509	56	9.9
Limousin	84	1,286	63.7	504	46	9.5
Charolais	95	1,349	63.7	523	69	9.6
LSD < 0.05		40	1.3	16	17	0.7

Table 6. USDA quality grade x yield grade for Hereford, Angus, and Red Angus (N=288).

	USDA yield grade, %				
Quality grade	1	2	3	4	Total
Low Prime	0.0	0.0	1.7	0.4	2.1
High Choice	0.0	0.7	2.1	1.7	4.5
Average Choice	0.0	1.7	7.3	2.8	11.8
Low Choice	2.8	18.4	29.5	17.0	67.7
Select	1.7	8.3	2.8	1.0	13.9
Standard	0.0	0.0	0.0	0.0	0.0
Total	4.5	29.2	43.4	22.9	100.0

Table 7. USDA quality grade x yield grade for steers with Simmental, Gelbvieh, Limousin, and Charolais sires (N=361).

	USDA yield grade, %				
Quality grade	1	2	3	4	Total
Low Prime	0.0	0.0	0.0	0.3	0.3
High Choice	0.0	0.0	0.3	0.0	0.3
Average Choice	0.3	1.9	3.1	0.3	5.5
Low Choice	8.3	27.2	14.4	1.7	51.5
Select	13.6	18.3	9.1	1.1	42.1
Standard	0.3	0.0	0.0	0.0	0.3
Total	22.4	47.4	26.9	3.3	100.0

Table 8. Sire breed least squares means for growth and puberty traits of heifers in Cycle VII of the GPE program (1999-2000 calf crops).

Sire breed of female	No.	400-d wt, lb	18 month wt, lb	18 month ht, cm	Frame score, sc	Pub exp, %	Pub wt, lb	Age at pub	Preg rate, %
Hereford	81	841	950	128.4	5.5	79.2	733	342	94
Angus	85	869	936	127.2	5.3	97.2	750	340	88
Red Angus	106	868	953	126.9	5.2	88.2	744	339	91
Simmental	103	849	961	130.2	5.9	91.6	757	335	90
Gelbvieh	111	807	922	128.8	5.6	91.5	711	322	83
Limousin	109	824	933	129.9	5.8	80.4	785	363	87
Charolais	103	828	950	129.5	5.8	88.5	758	348	91
LSD < 0.05		31	32	1.6	0.5	9.9	35	16	13

Table 9. Sire breed means for reproduction and maternal traits of F_1 females mated to produce their first calves at 2 years of age (2001 & 2002 calf crops).

Sire breed of female	No.	Calf crop Born, %	Calf crop Wnd, %	Calving diff score	Unassist births, %	Birth wt, lb	Surv to wn, %	200-d wt per Calf, lb	200-d wt per Cow exp, lb
Hereford	80	92	70	1.9	74	81.5	78	413	292
Angus	84	83	76	2.0	72	79.8	93	424	325
Red Angus	104	86	76	2.2	68	78.2	88	415	317
Simmental	98	86	69	1.5	86	79.6	82	442	309
Gelbvieh	109	79	68	2.2	64	83.6	86	447	307
Limousin	109	85	73	2.0	68	80.3	85	429	313
Charolais	97	87	73	2.1	69	81.6	83	430	315
LSD < 0.05		14	15	0.6	19	4.4	14	21	68

Table 10. Output/input differences among *Bos indicus* X *Box taurus* and *Bos taurus* x *Bos taurus* F_1 cows (Green et al., 1991).

Item	Overall mean	Breed group[a] (ratio) HAx	Pzx	Bmx	Swx
Progeny (126 days)					
Weight gain, lb	284	91	98	109	102
Energy consumed, Mcal ME	596	112	102	91	93
Dams (126 days)					
Milk production, lb/day	14.6	93	113	99	94
Cow weight, lb	1,229	98	100	105	96
Fat probe, in	0.46	89	92	104	115
Energy consumed, Mcal ME	3,305	94	105	104	97
Efficiency (138.5 days)					
Progeny gain, lb/Mcal ME calf + dam	0.07	94	95	105	97

[a]HAx = Hereford or Angus, Pzx = Pinzgauer, Bmx = Brahman, and Swx = Sahiwal.

Table 11. Output/input differences among *Bos taurus* X *Bos taurus* F_1 cows (Jenkins et al., 1991).

Item	Overall mean	Breed group[a] (ratio)					
		HAx	Rx	Bx	Gx	Mx	Cix
Progeny (138.5 days)							
Weight gain, lb	346	97	99	103	100	103	98
Energy consumed, Mcal ME	744	106	102	99	96	98	99
Dams (138.5 days)							
Milk production, lb/day	8.8	85	101	118	111	104	82
Cow weight, lb	1,138	98	91	97	100	107	107
Fat probe, in	0.25	124	101	91	93	90	101
Energy consumed, Mcal ME	3,787	91	96	105	105	100	104
Efficiency (138.5 days)							
Progeny gain, lb/Mcal ME calf + dam	0.08	103	103	99	97	103	95

[a]HAx = Hereford or Angus, Rx = Red Poll, Bx = Brown Swiss, Gx = Gelbvieh, Mx = Maine Anjou, Cix = Chianina sired F_1 crosses.

Table 12. Sire breed means for final weight and carcass traits of F_1 steers (447 days).

Sire breed	No.	Final wt, lb	Retail product, %	Retail product, lb	USDA Choice, %	14-d Shear, lb
Hereford	106	1,270	61.9	449	70.3	10.6
Angus	101	1,278	62.2	454	84.6	8.9
Brahman	76	1,199	63.8	449	30.4	12.9
Boran	138	1,116	62.6	400	47.2	11.3
Tuli	158	1,110	63.4	405	63.8	10.1
Nellore	97	1,224	65.0	465	51.4	----
LSD < 0.05		48	1.7	18	22.2	1.3

Table 13. Breed group means for reproduction and maternal traits.

Sire breed of female	Age at puberty		2 years of age			3 to 7 years of age		
				200-day wt			200-day wt	
	No.	Days	Calf crop wnd, %	Per calf, lb	Per cow exp, lb	Calf crop wnd, %	Per calf, lb	Per cow exp, lb
Hereford	152	355	73.8	419	300	88.7	474	422
Angus	130	351	74.4	437	313	86.3	493	426
Average	282	353	74.1	428	307	87.5	483	424
Brahman								
Original	82	429	54.3	456	238	85.9	511	440
Current	208	423	69.6	476	319	82.7	521	430
Average	244	426	62.0	466	279	83.2	516	435
Boran	206	396	83.3	444	357	86.2	488	421
Tuli	244	371	74.6	413	296	84.1	471	397
Nellore	82	406	75.1	463	324	91.6	514	461
LSD < 0.05		13	13.9	18	62	6.7	14	36

Table 14. Breed group means for preweaning traits of calves produced in Cycle VIII of the GPE program (2001 & 2002 calf crops).

Sire breed of calf	No. calves born	Calvings unassist, %	Calvings 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
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 < 0.05		3.4	0.20	3.0	11

Table 15. Sire breed means for final weight and carcass traits of F_1 steers produced in Cycle VIII of the GPE program (426 days, 2001 & 2002 calf crops).

Sire breed	N	ADG, lb/d	Final wt, lb	Retail product		Marb score	USDA Choice, %
				%	lb		
Hereford	102	3.02	1,245	61.8	466	515	52
Angus	103	3.15	1,283	60.0	469	548	71
Brangus	107	2.99	1,256	62.1	481	497	42
Beefmaster	103	3.10	1,296	61.2	482	483	35
Bonsmara	104	2.80	1,183	63.4	464	487	37
Romosinuano	102	2.71	1,150	64.4	452	488	37
LSD < 0.05		0.09	29	1.1	13	24	13

Table 16. Sire breed means for growth traits of heifers produced in Cycle VIII of the GPE program (2001 & 2002 calf crops).

Sire breed of female	No.	400-d wt, lb	18 months		Frame score, sc
			wt, lb	ht, cm	
Hereford	102	854	889	127.7	5.41
Angus	107	881	880	126.3	5.12
Brangus	47	870	904	129.3	5.74
Beefmaster	53	884	923	129.1	5.69
Bonsmara	51	832	889	126.7	5.20
Romosinuano	50	766	821	126.1	5.09
LSD < 0.05		26	25	1.2	0.24

Table 17. Sire breed means for puberty traits of heifers produced in Cycle VIII of the GPE program (2001 & 2002 calf crops).

Sire breed	No.	Age at puberty, days	Pregnancy rate, %
Hereford	102	325	86
Angus	107	312	83
Brangus	47	339	92
Beefmaster	53	343	97
Bonsmara	51	353	85
Romosinuano	50	359	90
LSD < 0.05		14	11

Notes: