Reproduction and Maternal Characteristics of Diverse Breeds of Cattle used for Beef production

Larry V. Cundiff,
Keith E. Gregory
U.S. Department of Agriculture,
Clay Center, NE 68933
and **Robert M. Koch**
University of Nebraska, Lincoln, NE 68583

Introduction

Grading up or straightbreeding to Shorthorns, Herefords and Angus was the dominant system employed in beef production from the late 1800's until the 1960's in the United States. Although most cattlemen had their favorite breed, the adage that "there is more variation within breeds than between breeds" was generally accepted as a truism among beef cattle breeders throughout this period. As Lush[1] pointed out, stockmen were misled by this attitude into believing that genetic differences between breeds were "not real after all" or at least not very important. Recognition of the importance of heterosis (difference between mean for F_1 crosses and mean for parental breeds) from diallel crossing experiments conducted in the 1960's and interest in increasing output components fo beef production, stimulated interest in crossbreeding to breeds with greater genetic potential for milk production, growth rate and mature size. As a result, a large number of breeds, introduced from Europe via quarantine facilities in Canada, became available to North American beef producers. Interest in the newly introduced breeds and in other breeds previously considered only for dairying coincided with the establishment of the Roman L. Hruska U.S. Meat Animal Research Center (MARC) in the late 1960's. The Germ Plasm Evaluation (GPE) Program was initiated in 1969 at MARC to characterize a broad spectrum of breeds that differed widely in genetic potential for growth rate, milk production, carcass composition and mature size. The purpose of this paper is to review results from the GPE program concerning genetic variation among breeds relative to that within breeds for reproduction and maternal traits important to beef production.

Germ Plasm Evaluation Program

The GPE Program has been conducted in four Cycles. Table 1 shows the mating plan for Cycles I, II, III and IV. Topcross performance of 26 different sire breeds have been, or are being, evaluated in calves out of Hereford and Angus dams or calves out of F_1 cross dams (see Table 1). These F_1 cross dams were bred to Brahman, Devon and Holstein sires in Cycle I and to Santa Gertrudis and Brangus sires in Cycle II. Semen from the same Hereford and Angus bulls has been used throughout to produce a control population of Hereford-Angus reciprocal crosses in each Cycle of the program. In addition to the repeated use of semen from control Hereford and Angus bulls, new samples of Hereford, Angus, and Charolais bulls born since 1982 are being added in Cycle IV to evaluate genetic trends within these breeds. To date, complete data are available only from the first three Cycles of the program. Thus, this review will focus only on data from twenty sire breeds involved in the first three Cycles of the program.

Data presenting results pooled over Cycle I, II and III were obtained by adding the average differences between Hereford-Angus reciprocal crosses (HAx) and other breed

TABLE 1. Sire Breeds used in Germ Plasm Evaluation Program

Cycle I (1970-72)	Cycle II (1973-74)	Cycle III (1975-76)	Cycle IV (1986-90)
F1 crosses from Hereford or Angus dams (Phase 2)			
Hereford	Hereford	Hereford	Hereford[a]
Angus	Angus	Angus	Angus[a]
Jersey	Red Poll	Brahman	Longhorn
S. Devon	Brown Swiss	Sahiwal	Salers
Limousin	Gelbvieh	Pinzgauer	Galloway
Simmental	Maine Anjou	Tarentaise	Nellore
Charolais	Chianina		Shorthorn
			Piedmontese
			Charolais
			Gelbvieh
			Pinzgauer
3-way crosses out of F1 dams (Phase 3)			
Hereford	Hereford		
Angus	Angus		
Brahman	Brangus		
Devon	Santa Gertrudis		
Holstein			

[a]Hereford and Angus sires, originally sampled in 1969, 1970 and 1971, have been used throughout the program. In Cycle IV, a new sample of Hereford and Angus sires produced after 1982 are being used and compared to the original Hereford and Angus sires.

groups (2-way and 3-way F_1 crosses) within each Cycle to the average of Hereford-Angus reciprocal crosses (HAx) over the three Cycles. The pooled results will be presented for nineteen F_1 crosses (2-way and 3-way) grouped into seven biological types based on relative differences (X lowest, XXXXXX highest) in growth rate and mature size, lean-to-fat ratio, age at puberty and milk production (Table 2). The breed group means presented in this review are from previous reports for birth and weaning traits[2, 3, 4, 5, 6, 7], age at puberty of heifers[8, 9, 10, 11, 12], and reproduction and maternal performance of F_1 cows[13]. Mean differences between breeds will be expressed in actual units and in standard deviation units for breeding value ($\sigma_g = \sigma_{ph}$; the phenotypic standard deviation, σ_p, and heritability, h^2, where computed from paternal half sib analyses of variance of data from the GPE program[14, 15, 16]).

TABLE 2. Breed Crosses grouped into six biological types on the basis of four major criteria[a]

Breed group	Growth rate & mature size	Lean to fat ratio	Age at puberty	Milk production
Jersey (J)	X	X	X	XXXXX
Hereford-Angus (HA)	XX	XX	XXX	XX
Red Poll (R)	XX	XX	XX	XXX
Devon (D)	XX	XX	XXX	XX
South Devon (Sd)	XXX	XXX	XX	XXX
Tarentaise (T)	XXX	XXX	XX	XXX
Pinzgauer (P)	XXX	XXX	XX	XXX
Brangus (Bn)	XXX	XX	XXXX	XX
Santa Gert. (Sg)	XXX	XX	XXXX	XX
Sahiwal (Sw)	XX	XXX	XXXXX	XXX
Brahman (Bm)	XXXX	XXX	XXXXX	XXX
Brown Swiss (B)	XXXX	XXXX	XX	XXXX
Gelbvieh (G)	XXXX	XXXX	XX	XXXX
Holstein (Ho)	XXXX	XXXX	XX	XXXXX
Simmental (S)	XXXXX	XXXX	XXX	XXXX
Maine Anjou (M)	XXXXX	XXXX	XXX	XXX
Limousin (L)	XXX	XXXXX	XXXX	X
Charolais (C)	XXXXX	XXXXX	XXXX	X
Chianina (Ci)	XXXXX	XXXXX	XXXX	X

[a]Increasing number of X's indicate relatively higher values.

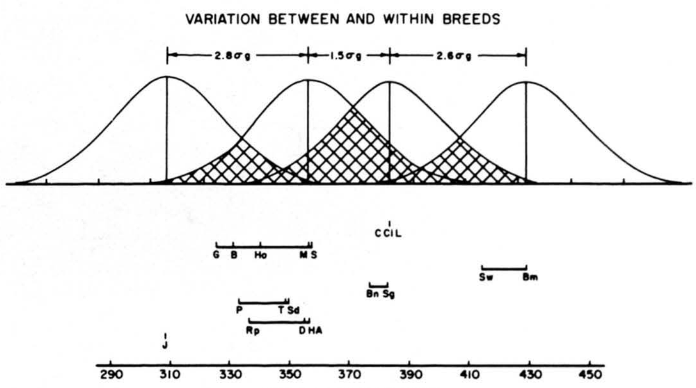
Reproductive Traits

In each Cycle, all F_1 cross females produced were retained to evaluate age and weight at puberty and reproduction and maternal performance through 7 or 8 years of age. The females were produced in the spring, weaned at about seven months of age, developed in a drylot during their first winter, and placed on improved pasture at about 13 months of age. They were maintained on improved pastures until their evaluation of reproduction and maternal performance was completed at 7 or 8 years of age. Supplementary grass hay and alfalfa hay was provided (about 11 to 13 kg/cow daily) during the winter months. The females were bred for spring calvings to produce terminal cross calves by unrelated sire breeds.

Age at Puberty

Genetic variation among breeds relative to that within breeds for age at puberty is shown in Figure 1[13]. Means for F_1 crosses are shown on the lower horizontal axis. The spacing on the vertical axis is arbitrary but the ranking of biological types (separate bars) from the bottom to top reflect, generally, increasing increments of mature size. Breed rankings within each biological type are noted within each bar. In Figure 1, differences are doubled in the upper horizontal scale to reflect variation among pure breeds relative to a standard deviation change in breeding value [$\sigma_g = (\sigma_p(h)$] within pure breeds. Frequency curves, shown for Jersey, the average of Hereford and Angus, Chiania, and Brahman reflect the distribution expected for breeding values of individual animals within pure breeds assuming a normal distribution (i.e., 68, 95 or 99.6% of the observations are expected to lie within the range bracketed by the mean ± 1, 2 or 3 standard deviations, respectively). The range for mean differences between breeds is estimated to be about 7.3 σ_g between Jersey and Brahman breeds. *Bos indicus* sired F_1 crosses had significantly older age at puberty than *Bos taurus* sired breed crosses. Both between and within breed sources of genetic variation were large and inportant for age at puberty.

Figure 1. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for age of heifers at puberty[13]. See Table 2 for abbreviations.



Heifers sired by bulls of breeds with large mature size (e.g., Charolais, Chianina) tended to be older at puberty than heifers sired by bulls of breeds with smaller mature size (Hereford, Angus). However, the relationship between mature size and age at puberty can be offset by associations with milk production. Breeds which have been selected for milk production reach puberty earlier than breeds of similar mature size and lean growth potential that do not have a history of selection for milk production (e.g., Simmental, Holstein, Brown Swiss and Gelbvieh versus Charolais and Chianina). Also, it appears that the *Bos indicus* breeds (Brahman and Sahiwal), which exceeded all other breeds in age at puberty, have been subjected to selection pressures that set them apart from *Bos taurus* breeds in age at which they exhibit their first estrus.

Although age at puberty differed signicantly among breeds, conception rate in yearling heifers did not differ consistently between breed groups reaching puberty at the oldest ages from those breed groups reaching puberty at the youngest ages. For example, conception rate of Brahman and Sahiwal cross heifers was very high in spite of their older age at puberty. The heifers in all breed groups were grown and developed under dry lot conditions on a moderately high energy diet (about 2.2 Mcal metabolizable energy [ME] per kg) and conception rate was not limited by variation observed among breed groups in age at puberty. It has been shown that heifers developed more slowly on diets with lower energy density, exhibit puberty at significantly older ages and have lower conception rates than heifers developed more rapidly when exposed to breeding as yearlings[17, 18, 19].

Reproduction.

Breed group means for calf weaned expressed as a percentage of cows exposed to breeding are summarized in Figure 2. Differences between breeds are not expressed in standard deviations because reproduction rate has a binomial distribution rather than a normal distribution. Only the most extreme differences in calf crop percentage born and weaned are statistically significant (about 4% for comparisons in the same Cycle and 6.0% for comparisons in different Cycles). The F_1 cows by *Bos taurus* breeds of large size and low genetic potential for milk production (Charolais, Chianina, Limousin), large size and high genetic potential for milk production (Brown Swiss, Gelbvieh, Holstein, Simmental and Maine Anjou), moderate size and low to moderate genetic potential for milk production (Hereford-Angus, Red Poll, Devon), small size and high genetic potential for milk production (Jersey), and moderately large and moderately high genetic potential for milk production (South Devon, Tarentaise, Pinzgauer) did not differ significantly from each other in calf crop percentage born or weaned. Results from other experiments have indicated that if added nutrient requirements of cows of large size higher milk production potential are not met, the intervals from calving to first estrus increase and conception rates decline [20, 21, 22]. The F_1 cows in each Cycle of the program have been run together on one feeding regime. The relatively high reproduction rate even for biological types with large size and high milk production potential indicates that the nutritional regime provided at MARC has been adequate to meet requirements for growth, maintenance and lactation, even of the most productive groups.

Calving traits.

Results for calving difficulity and birth weight are shown in Figure 3 and Figure 4. Breed of sire of calf means

Figure 2. Breed of sire of dam means for percentage calf crop weaned per cow exposed to breeding[13]. See Table 2 for abbreviations.

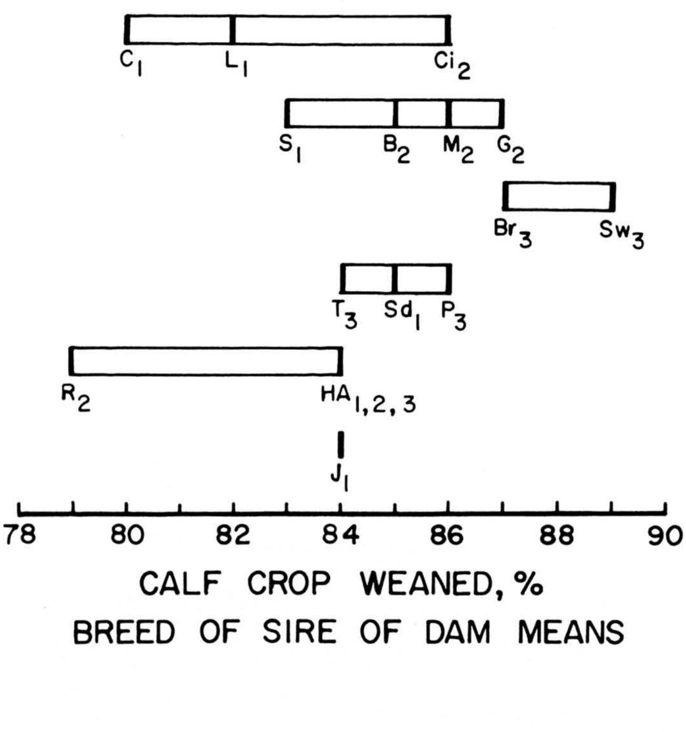
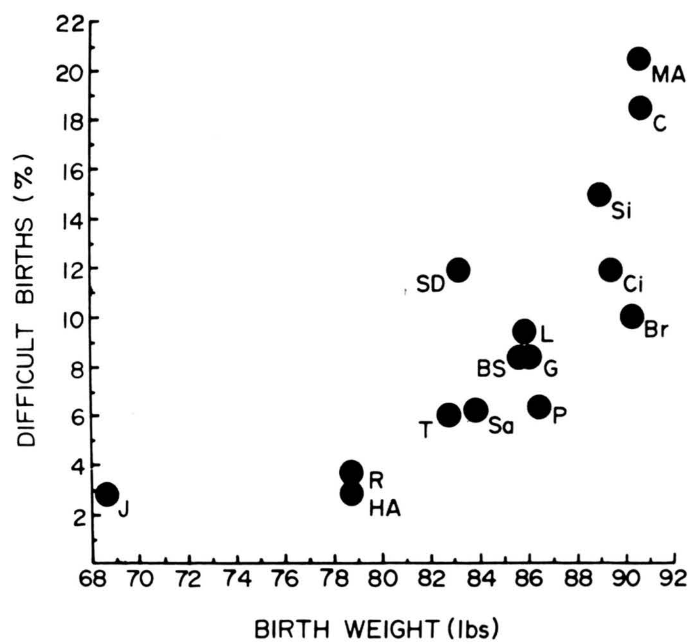
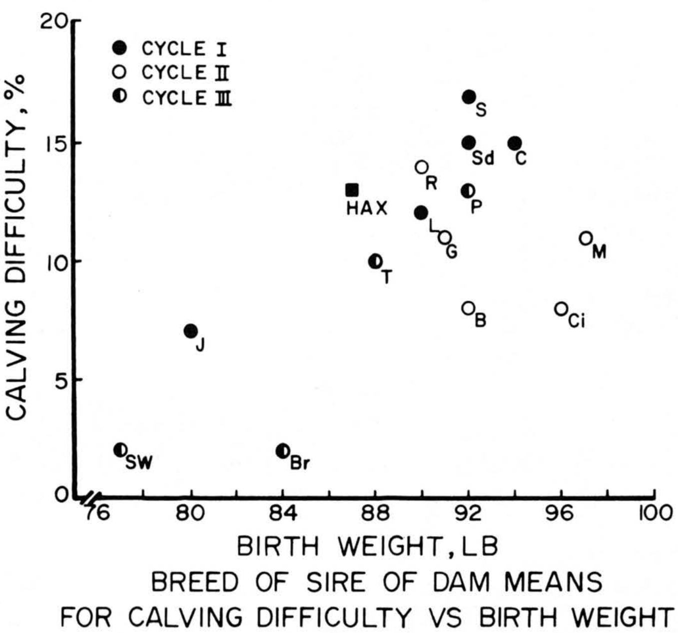


Figure 3. Breed of sire means for calving difficulty versus birth weight for Hereford and Angus females calving at 4 years of age or older[13]. See Table 2 for abbreviations.



for birth weight are plotted against those for calving difficulty in Figure 3. Breeds siring the heaviest calves at birth experience more calving difficulty than breeds siring calves with lighter birth weights. These results are for cows calving at 4 yrs of age or older. The association between calving difficulty and birth weight was greater in two- and three-year dams in Cycle I than in cows four years of age or older in Cycles I, II and III of the GPE program. Calving difficulty was in turn associated with increased calf mortality[23] and reduced rebreeding performance of dams (i.e., conception rate was 16% lower in females assisted at parturition than in females that were not assisted [24]).

Figure 4. Breed of sire of dam means for calving difficulty versus birth weight for Hereford and Angus females calving at 2 through 8 years of age[13]. See Table 2 for abbreviations.



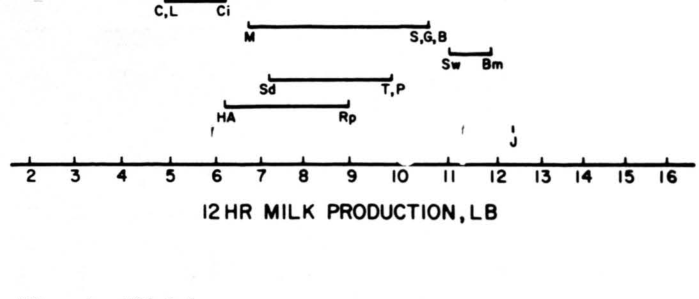
Breed of sire of dam means for birth weight and calving difficulty are plotted in Figure 4 for cows calving at 2 through 8 yrs of age. In F_1 cows, the relationship between calving difficulty and birth weight of the calf is not as great (Figure 4) as for sire of F_1 calf means (Figure 3). For example, progeny of Brown Swiss and Chianina cross cows had relatively heavy birth weights but below average calving difficulty. Birth weight and calving difficulty for the Brahman and Sahiwal sired F_1 females were remarkably low. When Brahman bulls were mated to Angus and Hereford dams, the Brahman sired F_1 calves had heavy birth weights, comparable to Chianina, Charolais and Maine Anjou sired calves (Figure 3). However, birth weights of Brahman sired F_1 cows were lighter than all breeds except Jersey and Sahiwal and calving difficulty less that 2% (Figure 4). The small birth weights and reduced calving difficulty of the Jersey are attributable to direct effects of calf genotype on birth weight, but the reduced birth weight and calving difficulty of progeny out of Brahman and Sahiwal sired F_1 cows are attributable to a pronounced maternal effect limiting fetal growth.

Maternal Traits

Milk Production

Breed group means for milk production (mean of three estimates based on calf weights before and after nursing obtained on a sample of 18 cows per breed group at 3 and 4 years of age) are shown in Figure 5. Among *Bos taurus* sired F_1 cows, breeds which have a history of selection for milk production (Jerseys excelled in milk production, followed by Simmental, Gelbvieh, and Brown Swiss, then by Tarentaise, Pinzgauer and Red Poll) produced higher levels of milk than breeds which do not have a history of selection for milk production (Charolais, Limousin, Chianina and Hereford-Angus). Maine Anjou F_1 cows produced relatively low levels of milk considering their history of selection for milk production. When breed group differences are doubled in the upper horizontal scale to reflect variation among pure breeds relative to a standard deviation change in breeding value within pure breeds, indications are that additive genetic variation between breeds is about equal to that within breeds for milk production.

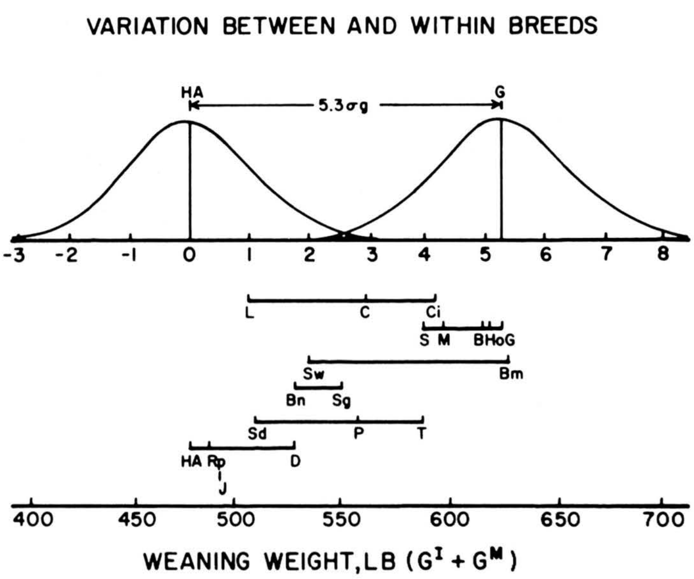
Figure 5. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for mean 12-hour milk production[13]. See Table 2 for abbreviations.



Weaning Weight.

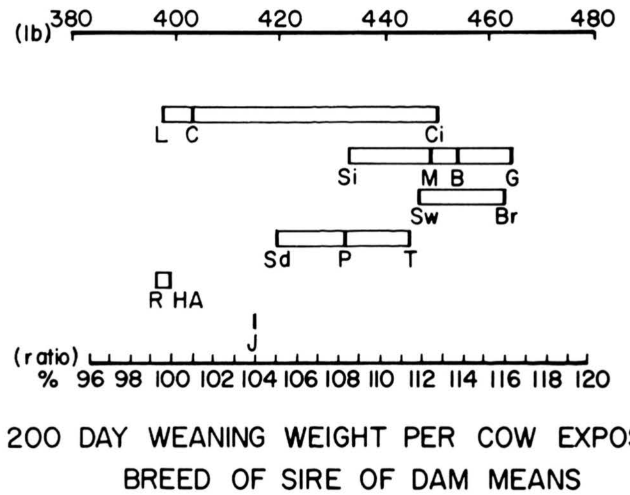
Breed group means for weaning weight per calf weaned are summarized in Figure 6. The range in differences between F_1 cow means for weaning weight per calf weaned (Devon to Holstein) was about $2.2\sigma_g$[13]. In Figure 6, differences between F_1 cross means $(1/4_g^{I} + 1/2_g^{M})$ are adjusted to a purebred basis ($g^I + g^M$). On a pureberd basis, the range in differences ($5.3\sigma_g$) is nearly as great as that expected among individuals within breeds ($6\sigma_g$). Results for weaning weight per calf weaned show strong associations with estimates of milk production (Figure 5) and with genetic potential for growth of F_1 cows. Weaning weight per calf weaned for F_1 cows by sire breeds of large size and low genetic potential for milk production (Charolais and Chianina) exceeded that for F_1 cows by sire breeds of moderate size and low genetic potential for milk production (Hereford-Angus and Devon), but not by as much as F_1 cows by sire breeds of large size and high genetic potential for milk production (Brown Swiss, Gelbvieh, Holstein, and Simmental). Weaning weight per calf weaned for F_1 cows by sire breeds of large size and low genetic potentail for milk production (Charolais and Chianina) were comparable to that for F_1 cows by sire breeds of moderately large size and moderately high genetic potential for milk production (South Devon, Tarentaise, Pinzgauer).

Figure 6. Breed of sire of dam means for 200 day weaning weight per calf weaned [13]. See Table 2 for abbreviations.



Breed group means for weaning weight per cow exposed to breeding are also summarized in Figure 7. In general, rankings for weaning weight per cow exposed to breeding correspond closely to those for weaning weight per calf weaned. Output was greatest for Zebu (Brahman and Sahiwal) and large size dual purpose breeds (Gelbvieh, Brown Swiss, Maine Anjou and Simmental). Output of dual purpose breeds with intermediate size (Pinzgauer, Tarentaise and South Devon) was intermediate to that of Hereford-Angus F_1 crosses and larger-higher milking dual

Figure 7. Breed of sire of dam means for 200 day weaning weight per cow exposed to breeding [13]. See Table 2 for abbreviations.



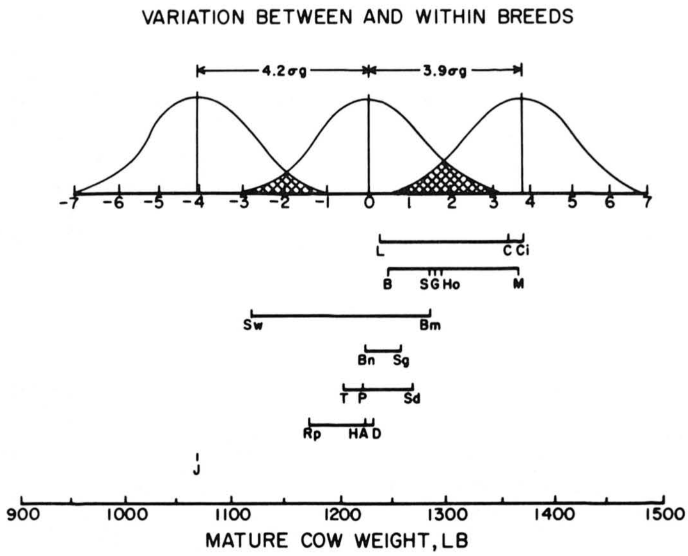
purpose breeds (Gelbvieh, Brown Swiss, Maine Anjou and Simmental). Output of Limousin and Charolais cross cows was similar to that of Hereford and Angus crosses. Extra growth rate of progeny out of Charolais cross cows was offset by a relatively higher calf crop percentage weaned for Hereford-Angus cross cows. Output of Chianina crosses was high relative to Hereford-Angus, Limousin and Charolais crosses due to relatively high calf crop percentages and weaning weight. Output of Jersey crosses exceeded that of Hereford-Angus crosses by about 4 percent reflecting higher milk production. The higher milk production of Red Poll crosses and weaning weights of progeny out of Red Poll F_1 crosses was offset by a lower calf crop weaned, so that differences between Red Poll and Hereford-Angus F_1 cross cows were small for 200-day weight per cow exposed.

Cow Size and Efficiency

Cow Weight.

Breed group means for cow weights at 7 years of age are shown in Figure 8. Mean weights of F_1 cows by sire breeds of large size and low genetic potential for milk (Charolais and Chianina) exceed those of F_1 cows by sire breeds of large size and high milk production (Brown Swiss, Gelbvieh, Holstein, and Simmental). Results for condition scores indicated that at least part of this difference in weight was accounted for by differences in fatness of the cows. Mean weights of F_1 cows by sire breeds of large size and high genetic potential for milk production (Brown Swiss, Gelbvieh, Holstein, Simmental) were higher than those of F_1 cows by sire breeds of moderate size and low genetic potential for milk production (Hereford-Angus and Devon).

Figure 8. Breed group means (lower axis) and genetic variation between and within breeds (upper axis) for cow weight at 7 years of age [13]. See Table 2 for abbreviations.



The variation among and within breeds in mature weight is vast and highly heritable. If the range of differences between F_1 crosses is doubled to reflect differences between (8.1 σg), the range is somewhat greater than that expected for breeding value of individuals within breeds (6 σg). In any given environment the mature weight of cows can be determined with reasonable precision by the breeds chosen and by the breeding value of individuals used within breeds for growth rate and mature size. The question becomes, what is the optimum mature weight for any given environment? Heavier cow weight increases output per head from the production system when cows are sold; however, heavier cow weight also increases nutrient requirements per cow for maintenance of the cow herd. Ferrell and Jenkins[25] have estimated daily maintence requirements of 130, 129, 145, and 160 kcal/kg$^{.75}$ for mature Angus or Hereford, Charolais, Jersey, and Simmental sired F_1 cows out of Hereford and Angus dams.

Cow efficiency.

Output/input differences of F_1 cow breed groups in Cycle II of the GPE Program were studied during a 138.5 day lactation interval[26]. In this experiment, F_1 cross cows out of Hereford and Angus dams and sired by Hereford or Angus (HAx), Red Poll (Rx), Brown Swiss (Bx), Gelbvieh (Gx), Maine Anjou (Mx) and Chianina (Cix) were fed to maintain their initial weight (see cow weight in table 3) for a 138 or 139 day period commencing at about 45 days postpartum in 1981 and 1982, respectively. The cows raising Simmental sired progeny were assigned to replicated pens (2 pens/year) of 12 cow calf pairs per pen. ME consumption was adjusted to zero bi-weekly weight change by regression procedures. Differences in progeny gain and ME consumption were not significant (P .05). Perhaps this is not surprising for progeny groups that differed for direct breed effects only by a 1/4 contribution from their maternal grandsire (i.e., all progeny were 1/2 Simmental, and either 1/4 Hereford or 1/4 Angus). Significant differences were found among F_1 cow breed groups for milk production, cow weight, fat thickness (average of estimates measured at beginning and end of experiment) and energy consumption. The Hereford-Angus cross cows required significantly less feed than the Brown Swiss, Gelbvieh Maine Anjou, and Red Poll sired F_1 cross cows and Red Poll sired F_1 cross cows required less than Glebvieh, Maine Anjou and Chianina sired F_1 cross cows. The Hereford-Angus, Red Poll and Maine Anjou sired F_1 cross cows were significantly more efficient than the higher milking Brown Swiss and Gelbvieh cross cows and the larger sized Chianina F_1 cross dams, possibly due to greater benefits of complementarity when raising progeny by Simmental sires. Comementarity is provided for in terminal sire systems of crossbreeding when cows of small size are raising progeny by sires of a different breed that excels in lean tissue growth rate.

TABLE 3. Output/input differences among F_1 cows of diverse biological type[26]

Item	Overall mean	Breed group[a] HAx	Rx	Bx	Gx	Mx	Cix
Progeny (138 days)							
Weight gain, lb	346	97	99	103	100	103	98
Energy consumed, Mcal ME	744	106	102	99	96	98	99
Dams (138 days)							
Milk production, lb/day	8.8	85	101	118	111	104	82
Cow weight, lb	1138	98	91	97	100	107	107
Fat probe, in	.25	124	101	91	93	90	101
Energy consumed, Mcal ME	3787	91	96	105	105	100	104
Efficiency (138 days)							
Progeny gain, lb/ Mcal ME intake by cow and calf	.077	103	103	99	97	103	95

[a] Ratio percentages computed relative to overall mean where HAx = Hereford or Angus, Rx = Red Poll, Bx = Brown Swiss, Gx = Gelbvieh, Mx = Maine Anjou and Cix = Chianina sired F_1 crosses out of Hereford and Angus dams.

Feed required for maintenance and lactation by F_1 cows sired by Brahman, Sahiwal, Pinzgauer and Hereford or Angus sires out of Hereford or Angus dams in Cycle III of the GPE program were studied in a drylot during a 126 day summer period in 1988 in mature cows [27] (table 4). Breed groups differed in size, milk yield, progeny gains and feed required for maintence. Efficiency (gain of calf during 126 day preweaning period, kg/Mcal ME consumed by cow and calf) of *Bos indicus x Bos taurus* F_1 cross (Brahman x Hereford, Brahman x Angus, Sahiwal x Hereford, Sahiwal x Angus) cows was 10% greater than that of *Bos taurus x Bos taurus* F_1 cross (Hereford x Angus, Angus x Hereford, Pinzgauer x Angus) cows.

Increases in output associated with increased size tend to be offset by increases in feed requirements for

TABLE 4. Output/input differences among *Bos indicus x Bos taurus* and *Bos taurus x Bos taurus* sources of Germ Plasm [27]

Item	Overall mean	Breed group[a] HAx	Pzx	Bmx	Swx
Progeny (126 days)					
Weight gain, lb	284	91	98	109	102
Energy consumed, Mcal ME	593	112	102	91	94
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	.46	89	92	104	115
Energy consumed, Mcal ME	3,305	94	105	104	97
Efficiency (126 days)					
Progeny gain, lb/ Mcal ME intake by cow and calf	.073	94	95	106	106

[a] Ratio percentages computed relative to overall mean where HAx = Hereford or Angus, Pzx = Pinzgauer, Bmx = Brahman and Swx = Sahiwal sired F_1 crosses out of Hereford and Angus dams.

maintenance, so that differences in efficiency are small [26, 27, 28, 29, 30]. Increases in output of progeny weight associated with increasing increments of milk production of dams appear to be more than offset by increased feed requirements for lacation [26, 30, 31]. The key to efficient production is synchronizing the genetic potential for mature weight and milk production with the feed resources which can be provided most economically.

Matching Germ Plasm to Climatic Environment

Use of *Bos indicus* germ plasm is strongly favored in the subtropics (e.g., Gulf coastal regions of U.S.). In a cooperative effort between the Subtropical Agricultural Research Station, (ARS, USDA and the University of Florida), Brooksville, Florida and MARC, a sample of about 60 females each by Brahman, Sahiwal, Pinzgauer and Hereford or Angus sired F_1 crosses out of Hereford and Angus dams produced at MARC in Cycle III of the GPE program were transferred to Florida, to evaluate genotype-environment interactions. Data are shown in Table 5 for reproduction and maternal performance of the F_1 cows when mated to Red Poll sires to produce their first calves and to Simmental sires for their subsequent calves through 5 or 6 years of age. Weaning weight per cow exposed was signifcantly 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. Part of this advantage is likely attributable to the extra heterosis in *Bos taurus x Bos taurus* crosses [32, 33]. Birth weights were much lighter for all breeds in Florida than in Nebraska and calving difficulty was observed only rarely in any breed. Cooperative studies (unpublished) involving comparable germ plasm at MARC and Louisiana or Texas have also demonstrated that birth weight of calves are significantly lighter in warm climates than in cold climates. At

TABLE 5. Reproduction and maternal performance of Bos indicus x *Bos taurus* and *Bos taurus x Bos taurus* breed crosses in temperate (MARC, Clay Center, NE) and subtropical environments (STARS, Brooksville, FL)

Trait	Location	Breed group of dam[a] HAx	Pzx	Bmx	Swx	Av.
Pregnancy rate, %	NE	92	93	94	95	94
	FL	83	80	86	89	85
Calf survival,%	NE	93	91	92	93	92
	FL	98	94	98	97	97
Birth wt, lb	NE	81	88	78	72	80
	FL	60	69	64	56	62
Weaning wt per calf, lb	NE	498	536	560	529	531
	FL	437	473	553	523	497
Weaning wt per cow exposed, lb	NE	428	453	482	469	459
	FL	356	357	463	454	407

[a]HAx = Hereford or Angus, Pzx = Pinzgauer, Bmx = Brahman and Swx = Sahiwal sired F_1 crosses out of Hereford and Angus dams.

MARC, fall born calves (last trimester of gestation during summer months) are about 5 lb lighter than spring born calves (gestation during winter months) of comparable breeding. The reduction in birth weight from Nebraska to Florida is somewhat greater for progeny of *Bos taurus x Bos taurus* cross F_1 cows than for progeny of *Bos indicus x Bos taurus* cross F_1 cows. However, as noted above, birth weights of calves out of *Bos indicus x Bos taurus* F_1 dams tend to be less than those of calves out of *Bos taurus x Bos taurus* F_1 dams in climatic zones.

Although calving difficulty was much less for progeny of *Bos indicus x Bos taurus* F_1 cross cows than for *Bos taurus x Bos taurus* F_1 cross cows in the temperate Nebraska climate, this advantage was not accompanied by increased calf survival (Table 6) as would be expected in *Bos taurus* breed crosses[23]. Recent results, involving reciprocal backcross and F_2 calves differing in the ration of *Bos indicus* (Brahman, Sahiwal) to *Bos taurus* (Hereford, Angus, Pinzguer) inheritance (0:100, 25:75, 50:50 and 75:25), showed that mortality increased as the proportion of *Bos indicus* inheritance increased in calves born during early spring months (March-April)[34], especially as average temperature on the day of a calf's birth decreased (Table 6). Calves with 50% or more *Bos indicus* inheritance were not as well adapted as calves with only 25% or less *Bos indicus* inheritance to calving conditions which can be characterized as cold (mean daily temprature, 40 F; cold and wet (45 F and .1 inch precipitation; or cold and windy (Ko = 800 Kcal/m_2 /hour). Results in Table 5 and Figure 7 are for progeny with 25% *Bos indicus* inheritance, progeny of first calf heifers were by Red Poll sires and all progeny at subsequent calvings were by Simmental sires.

TABLE 6. Least squares means for breed group and average daily temperature classes

Temp. class (F^o)	0:100	Bos indicus:Bos taurus ratio 25:75	50:50	75:25	Mean
Number of calves					
≥52	118	33	57	42	250
46 to <52	71	26	42	17	156
41 to <46	75	11	28	26	140
36 to <41	73	29	44	25	171
30 to <36	89	26	50	21	186
<30	53	14	28	12	107
Total	479	139	249	143	1010
Mortality, birth to weaning (MORT, %)					
≥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
Mean	3	3	8	21	
Heat chamber required (HEAT, %)					
≥52	0	0	0	0	0
46 to <52	0	0	10	17	7
41 to <46	4	0	2	27	8
36 to <41	14	17	30	32	23
30 to <36	16	34	54	27	33
<30	29	17	66	86	50
Mean	11	11	27	31	
Mortality or heat chamber (MORT-HEAT, %)					
≥52	2	0	4	1	2
46 to <52	2	5	10	20	9
41 to <46	9	0	6	54	17
36 to <41	16	21	34	52	30
30 to <36	17	36	64	60	44
<30	32	25	76	86	55
Mean	13	14	32	46	

Summary

Significant variation exists among breeds for age at puberty, calving difficulty, milk production, weaning weight of progeny and cow size. The range for differences between breeds was comparable in magnitude to the range for breeding value of individuals within breeds for most of these traits which are important in cow herds. Thus, significant genetic change can result from selection both between and within breeds.

Faster gaining breed groups of larger mature size tend to reach puberty at a later age than the slower gaining breed groups of smaller mature size. Breeds that have been selected for milk production reach puberty at younger ages than those that have not been selected for milk production.

Output is maximum for cows that excel in milk production and lean growth potential if nutrient requirement are met to support growth, maintenance and lacatation and high levels of reproduction. Differences in output tend to be offset by differences in input for maintenance and lactation so that differences in efficiency are relatively small. To optimize reproduction rate in the cow herd, mature size and milk production level should be matched with the climatic environment and feed resources available.

Brahman and Sahiwal cross cows excel in weaning weight per cow exposed and cow efficiency, perhaps because of extra heterosis in *Bos indicus x Bos taurus* crosses relative to *Bos taurus x Bos taurus* crosses. However, calves with 50% or more *Bos indicus* inheritance are not as well adapted as calves with only 25% or less *Bos indicus* inheritance to calving conditions which can be characterized as cold (mean daily temperature, < 41°F); cold and wet (< 46°F and ≥0.1 inch precipitation); or cold and windy (Ko ≥ 800 Kcal/m_2/hour).

References

1. Lush, J.L. 1945. Animal Breeding Plans. Iowa State University Press. 2. Smith, G. M., D. B. Laster and K. E. Gregory. 1976. Characterization of biological types of cattle. II. Dystocia and preweaning growth. J. Anim. Sci. 43:27-36. 3. Gregory, K. E., L. V. Cundiff, G. M. Smith, D. B. Laster and H. A. Fitzhugh, Jr. 1978. Characterization of biological types of cattle - Cycle II: I. Birth and weaning traits. J. Anim. Sci. 47:1022-1033. 4. Notter, D. R., L. V. Cundiff, G. M. Smith, D. B. Laster and K. E. Gregory. 1978. Characterization of biological types of cattle. VI. Transmitted and maternal effects on birth and survival traits in progeny of young cows. J. Anim. Sci. 46:892-907. 5. Notter, D. R., L. V. Cundiff, G. M. Smith, D. B. Laster amd K. E. Gregory. 1978. Characterization of biological types of cattle. VII. Milk production in young cows and transmitted and maternal effects on preweaning growth of progeny. J. Anim. Sci. 46:908-921. 6. Gregory, K. E., G. M. Smith, L. V. Cundiff, R. M. Koch and D. B. Laster. 1979. Characterization of biological types of cattle - Cycle III: I. birth and weaning traits. J. Anim. Sci. 48:271-279. 7. Anonymous. 1977. Germ Plasm Evaluation Program Progress Report No. 5. U.S. Meat Animal Research Center, Agr. Res. Serv., U.S. Dept. of Agr., ARS-NC-55. 8. Laster, D. B., G. M. Smith and K. E. Gregory. 1976. Characterization of biological types of cattle. IV. Postweaning growth and puberty of heifers. J. Anim. Sci. 43:63-70. 9. Young, L. D., L. V. Cundiff, J. D. Crouse, G. M. Smith and K. E. Gregory. 1978. Characterization of biological types of cattle. IX. Postweaning growth and carcass traits of three-way cross steers. J. Anim. Sci. 46:1178-1191. 10. Laster, D. B., G. M. Smith, L. V. Cundiff and K. E. Gregory. 1979. Characterization of biological types of cattle (Cycle II). II. Postweaning growth and puberty of heifers. J. Anim. Sci. 48:500-508. 11. Anonymous. 1978. Germ Plasm Evaluation Program Progress Report No. 6. U.S. Meat Animal Research Center, Agr. Res. Serv., U.S. Dept. of Agr., ARM-NC-2. 12. Gregory, K. E., D. B. Laster, L. V. Cundiff, G. M. Smith and R. M. Koch 1979. Characterization of biological types of cattle - Cycle III: II. Growth rate and puberty in heifers. J. Anim. Sci. 49:461-471. 13. Cundiff, L. V., K. E. Gregory, R. M. Koch and G. E. Dickerson. 1986. Genetic diversity among cattle breeds and its use to increase beef production efficiency in a temperate environment. Proc. 3rd World Congr. on Genet. Appl. to Livestock Prod. Lincoln, NE, USA. IX:271-282. 14. Koch, R. M., L. V. Cundiff and K. E. Gregory. 1982. Heritabilities and genetic, environmental and phenotypic correlations of carcass traits in a population of diverse biological types and their

implications in selection programs. J. Anim. Sci. 55:1319-1329. 15. MacNeil. M. D., L. V. Cundiff, C. A. Dinkel and R. M. Koch. 1984. Genetic correlations among sex limited traits in beef cattle. J. Anim. Sci. 58:1171-1180. 16. Cundiff, L. V., M. D. MacNeil, K. E. Gregory and R. M. Koch. 1986. Between and within-breed genetic analysis of calving traits and survival to weaning in beef cattle. J. Anim. Sci. 63:27-33. 17. Wiltbank, J. N., K. E. Gregory, L. A. Swiger, J. E. Ingalls, J. A. Rothlisberger and R. M. Koch. 1966. Effects of heterosis on age and weight at puberty in beef heifers. J. Anim. Sci. 25:744-751. 18. Wiltbank, J. N., C. W. Kasson and J. E. Ingalls. 1969. Puberty in crossbred and straightbred beef heifers on two levels of feed. J. Anim. Sci. 29:602-605. 19. Ferrell, C. L. 1982. Effects of postweaning rate of growth on onset of puberty and productive performance of heifers of different breeds. J. Anim. Sci. 55:1272-1283. 20. Deutscher, G. H. and J. V. Whiteman. 1971. Productivity as two-year-olds of Angus-Holstein crossbreds compared to Angus heifers under range conditions. J. Anim. Sci. 33:337-342.21. Kropp, J. R., D. F. Stephens, J. W. Holloway, J. V. Whiteman, L. Knori and R. Totusek. 1973. Performance on range and in drylot of two-year-old Hereford, Hereford x Holstein and Holstein females as influenced by level of winter supplementation. J. Anim. Sci. 37:1222-1232. 22. Holloway, J. W., D. F. Stephens, J. V. Whiteman and R. Totusek. 1975. Performance of three-year-old Hereford, Hereford x Holstein and Holstein cows on range and in dry lot. J. Anim. Sci. 40:114-125. 23. Laster, D. B. and K. E. Gregory. 1973. Factors affecting dystocia and effects of dystocia on subsequent reproduction in beef cattle. J. Anim. Sci. 37:1092-1097. 24. Laster, D. B., H. A. Glimp, L. V. Cundiff and K. E. Gregory. 1973. Factors affecting dystocia and effects of dystocia on subsequent reproduction in beef cattle. J. Anim. Sci. 36:695-705. 25. Ferrell, C.L. and T. G. Jenkins. 1984. Energy utilization by mature, nonpregnant, nonlactating cows. J. Anim. Sci. 58:234-243. 26. Cundiff, L. V., C. L. Ferrell and T. G. Jenkins. 1983. Output/input differences among F_1cows of diverse biological type. J. Anim. Sci. 57(Suppl. 1):148. (Abstr.). 27. Green, R. D., L. V. Cundiff and G. E. Dickerson. 1989. Life-cycle efficiency of cow-calf production to weaning of *Bos indicus-Bos taurus versus Bos taurus-Bos taurus* sources of germ plasm. J. Anim. Sci. 67 (Suppl. 1):90. (Abstr.). 28. Marshall, D. W., W. R. Parker and C. A. Dinkel. 1976. Factors affecting efficiency to weaning in Angus, Charolais and reciprocal cross cows. J Anim. Sci. 43:1176-1187. 29. Bowden, D. M. 1980. Feed utilization for calf production in the first lactation by 2-year-old F_1 crossbred beef cows. J. Anim. Sci. 51:304-315. 30. Jenkins, T. G. and C. L. Ferrell. 1983. Estimated production efficiencies of crossbred cows. J. Anim. Sci. 57(Suppl. 1):154. (Abstr.).31. Holloway, J. W., D. F. Stephens, J. V. Whiteman and R. Totusek. 1975. Efficiency of production of 2- and 3-year-old Hereford, Hereford x Holstein and Holstein cows. J. Anim. Sci. 41:855-867. 32. Cartwright, T. C., G. F. Ellis Jr., W. E. Kruse and E. K. Crouch. 1964. Hybrid vigor in Brahman-Hereford crosses. Texas Agr. Exp. Sta. Tech. Monogr. 1. 33. Koger, M., F. M. Peacock, W. G. Kirk and J. R. Crockett. 1975. Heterosis effects on weaning performance of Brahman-Shorthorn calves. J. Anim. Sci. 40:826. 34. Josey, M. J., L. V. Cundiff, R. M. Koch, K. E. Gregory and G. L. Hahn. 1987. Cold tolerance and mortality of *Bos indicus vs Bos taurus* calves. J. Anim. Sci. 65(Suppl. 1):208 (Abstr.).